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Fruit Crops 1982: A Summary of Research

The Ohio State University
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ON THE COVER: Investigations are conducted in the greenhouse to support field studies on fruit crops. Graduate Research Associate Rebecca Darnell is measuring net photosynthesis on spur leaves of Starkrimson Delicious trees in bloom. This is part of a larger effort to determine the importance of spur leaves on fruit size, set, and quality. Trees for these studies were specially developed by grafting a spur system field tree onto MM106 rootstocks already growing in pots. After hand pollination, many of these trees carried several fruit to harvest. These small fruiting trees provide a unique research tool to study factors influencing fruit growth under conditions which avoid environmental hazards such as frost.

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Influence of Six Rootstocks and Herbicides on Growth, Cropping, and Fruit Quality of Blaxtayman Apple Trees[1]

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INTRODUCTION

Production efficiency of apple trees and orchards can be improved by using rootstocks (5) and planting more intensively (6). Intensive plantings require optimum soil management if they are to achieve their potential, and herbicides play an increasing role in preventing weed competition. The study reported here was established to evaluate the performance of six rootstocks in southern Ohio and the influence that various herbicide treatments had on rootstock performance.

MATERIALS AND METHODS

In 1968, Blaxtayman trees were planted at the Jackson branch of OARDC in southern Ohio in a Gilpin-Latham soil with less than desirable internal soil drainage. The trees were planted 9.2 m (30 ft) between rows and the following tree spacings in the row: M9 and M26 at 2.8 m (9 ft); M7, MM106, and MM111 at 5.5 m (18 ft); and apple seedling at 7.7 m (25 ft) with the trees on M9 and M26 supported by wooden posts by each tree. The trees were trained as central leaders without the use of limb spreaders and received standard pesticide and fertilization programs. Various cultivars used as guard trees between the plots served as pollenizers.

Herbicides were applied in a band at the following rates of active ingredient per acre: Casoron, 6 lb; Paraquat, 2 qt; Amazine, 4 lb; Diuron, 4 lb; Sinbar, 4 lb; and Cytrol, 1.5 lb. The spreader X77 (8 oz/a) was used with all Paraquat treatments. In 1972, the Amazine treatment was changed to Simazine (4 lb/a) and in 1973 Cytrol was changed to Roundup (2 qt/a). Treatments were as follows from 1973 to 1981: 1) check, hand hoed as needed; 2) Casoron + Paraquat; 3) Simazine; 4) Simazine + Paraquat; 5) Diuron + Paraquat; 6) Diuron + Sinbar; 7) Roundup + Diuron; 8) Sinbar. The treatments were arranged as a split plot with herbicide as the whole plot and rootstocks as the split plots with 4 replications for a total of 192 trees.

In addition to yearly tree growth and yield data, a five-fruit sample from six replicate trees of each rootstock were sampled for fruit firmness approximately Sept. 10 and 20 before harvest, and at harvest (approximately Oct. 1) in 1979 and 1980. The fruit for these measurements were selected from well exposed locations and uniformity of size on all trees. The study was terminated in 1981 after 14 years of growth.

RESULTS AND DISCUSSION

Blaxtayman trees on apple seedling rootstock were larger than trees on any other rootstock in trunk circumference and tree spread (Table 1). Based on trunk circumference with apple seedling used as 100%, the rootstocks resulted in the following dwarfing percentages: MM111, 13%; MM106, 16%; M7, 24%; M26, 58%; M9, 60%. The reduction in tree size induced by MM111 and MM106 was not enough to greatly change orchard management practices such as sprayer size, pruning time, or method or amount of area to be herbicided.

[1]The authors thank Harold M. Racer and John C. Schmid for technical assistance and Robert McConnell, manager of the Jackson Branch, for orchard care.

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TABLE 1.—Influence of Six Rootstocks on Growth, Yield, and Tree Loss of Blaxtayman Apple Trees at the Jackson Branch, OARDC.

	Tree Size 1981					Accumulated Yield			
Rootstock	Trunk Circumference (cm)	Change in Trunk Circumference 1980-81 (cm)	Height (m)	Spread (m)	Percent Tree Loss	Yield/Tree (lb)	Production Efficiency lb/cm²	Yield/Acre (bu) Calculated*	Yield/Acre (bu) Actual Spacing
Apple Seedling	77.0a†	4.1a	5.5a	6.4a	3.1	848b	18.3d	1453	1171
M7	58.6c	2.5b	4.7b	5.3c	18.8	1097b	43.0b	2664	2115
M9	31.1d	1.4c	3.1c	3.4d	37.5	466c	57.8a	2307	1786
M26	32.7d	1.7bc	3.0c	3.3d	53.0	492c	51.5ab	2436	1886
MM106	64.5b	3.5a	5.4a	5.7bc	16.2	1451a	44.1b	2936	2798
MM111	67.3b	4.3a	5.5a	5.9b	6.7	1110b	30.1c	2246	2140

*Based on a spacing of actual tree spread in the row at 13 yr of age plus actual tree spread plus 8 feet between rows.
†Means with a letter in common are not different, LSD .05.

TABLE 2.—Yearly Performance of Blaxtayman on Six Rootstocks Planted in 1968 at the Jackson Branch, OARDC.

	Yield/Year (bu/acre)*					
Rootstock	1976	1977	1978	1979	1980	1981
Apple Seedling	36	329	275	70	700	55
M7	145	579	613	223	1014	187
M9	175	472	584	194	800	173
M26	182	548	624	269	373	250
MM106	147	710	610	361	982	125
MM111	62	433	438	448	875	82

*Based on actual tree spread in the row at 13 years and a between row spacing of spread plus 8 feet.

In an attempt to maintain the trees at a height of 4.6 m (15 ft), significant containment pruning was practiced in the later years on trees on apple seedling, MM106, and MM111. As noted by the change in trunk circumference between 1980 and 1981, these rootstocks (apple seedling, MM106, MM111) are still making the greatest amount of vegetative growth and will require the greatest amount of containment pruning in the future. The shorter height of trees on the other rootstocks was mostly a rootstock and not a pruning effect.

Trees on MM106 and MM111 exceeded their allotted row space of 5.5 m (18 ft), while trees on M7 had not quite filled this space after 14 years of growth. Trees on M9 and M26 had exceeded the 2.8 m (9 ft) of space allotted due mostly to the very spreading nature with very open canopies of trees on these stocks. Extension growth on these stocks was only moderate and excessive crowding and shading would not be encountered at the spacing utilized. Trees on apple seedling had not yet filled the 7.7 m (25 ft) of space allotted but were still making vigorous growth and should not be planted closer.

Based on the results of 14 years of tree growth records in this planting, row spacing recommendations for the standard growth habit cultivars on this soil type and these rootstocks would be as follows: apple seedling, 6.8-7.7 m (22-25 ft); MM106 and MM111, 6.2-6.8 m (20-22 ft); M7, 4.3-5.5 m (14-18 ft); M9 and M26, 2.5-3.0 m (8-10 ft).

Apple seedling and MM111 rootstocks produced the best tree survival in this planting (Table 1). Tree losses on M7 and MM106 were 16-18% and bordered on being unacceptable, while losses encoun-

TABLE 3.—Influence of Six Rootstocks on Fruit Firmness and Soluble Solids of Blaxtayman at the Jackson Branch, OARDC.

	1979					
	9/10	9/20	10/1*		1/14	
Rootstocks	Firmness (lb)	Firmness (lb)	Firmness (lb)	SS %	Firmness (lb)	SS %
Apple Seedling	17.3d†	16.0cd	15.6c	14.8cd	11.2c	16.1b
M7	19.5b	18.0ab	17.6b	16.6a	12.9ab	17.9a
M9	19.1bc	17.5bc	17.4b	16.4a	13.6a	17.5a
M26	21.3a	19.2a	19.2a	16.0ab	13.1a	17.7a
MM106	18.3bcd	16.5cd	16.5bc	15.2bc	12.0bc	16.1b
MM111	17.5cd	15.6d	16.3bc	14.2d	11.7c	16.2b

	1980						
	9/11	9/20	10/1*	11/5		12/17	
Rootstocks	Firmness (lb)	Firmness (lb)	Firmness (lb)	Firmness (lb)	SS %	Firmness (lb)	SS %
Apple Seedling	25.5	22.7bc	20.5d	13.0	13.6	11.5	13.9c
M7	25.1	23.7ab	21.9bc	14.2	13.9	11.9	15.4a
M9	26.5	23.5abc	22.0abc	13.1	13.7	11.5	14.7abc
M26	26.0	24.3a	23.2a	13.5	14.5	12.1	15.1ab
MM106	25.3	23.2bc	22.4ab	13.7	13.7	11.9	14.3bc
MM111	24.9	22.5c	21.0cd	13.5	13.8	11.7	14.6abc

*Normal harvest date.
†Means with a letter in common are not different, LSD .05.

tered with M9 and M26 were certainly unacceptable. A severe windstorm in 1973 resulted in a number of trees on M9, M26, and M7 breaking at the union, and slow attrition on MM106 occurred over the years due to winter injury-collar rot symptoms. Blaxtayman on M26 had a large overgrowth at the union; they were very variable in size and generally smaller than other cultivars on this rootstock. Incompatibility between this cultivar and rootstock (4) and intolerance of soils with less than desirable internal drainage (3) are probable causes of the severe losses encountered with this rootstock and the reason it is not recommended for most Ohio soils. These relationships have been reported previously (3, 4).

Trees on apple seedling had the lowest production efficiency and calculated bushels per acre of any rootstock in this study (Table 1). If large tree size is desired, trees on MM111 have greater productive efficiency and yields per acre than apple seedling. Trees on MM106 had the highest yield per tree and M9 and M26 the highest productive efficiency. Trees on M7 were equal to MM111 in yield per tree, even though M7 trees were smaller and could be planted closer.

A comparison of yield per acre either calculated on actual tree size or the spacings actually used in the study indicates the dramatic reduction in yield potential when small efficient stocks such as M9 and M26 are given excessive space between the rows. The yield potential of trees on M7 is also quickly lost if more space is allotted than the trees require.

Trees on the larger rootstocks (MM106, MM111, and apple seedling) had similar yields, with each method of calculation indicating that the spacing allotted was effectively used by the tree.

The potential for trees on M9 and M26 to begin bearing early was in evidence during the period from 4 through 8 years of age (1971-1975). In the full production years (1976-1981), trees on the larger clonal rootstocks equaled or exceeded the yield per acre on the dwarfing stocks (Table 2). Trees on all clonal rootstocks outyielded trees on apple seedling throughout the period of the trial. The low yields in 1981 resulted from inadequate fruit thinning in 1980 and severe containment pruning of the larger trees prior to the 1981 growing season. Trees on MM106 appeared to be slightly more consistent in cropping than most of the other rootstocks.

Generally fruit quality from trees on MM106, MM111, and apple seedling as judged by firmness and soluble solids was lower than fruit from M26 (Table 3). Fruit from trees on M9 and M7 generally fell between the above groups in the quality attributes measured. The one measurement out of storage in January 1979 indicates that general influence of rootstock on firmness and soluble solids may continue through storage. Although not as clearly defined, the storage data in 1980 follow the same trends. These data dispute grower comments that fruit from M9 was less firm than from standard trees. However, it must be stressed that great care in these studies was taken to sample the same size fruit from each rootstock.

There is not much information on the influence of rootstocks on storage behavior of fruit. Kidd and West (7) failed to detect any differences in the onset of the climateric in Cox's Orange Pippin apples from trees of M1, M5, M9, and M12 rootstocks, but found that fruit from trees on M1 and M5 retained their flavor and condition during storage longer than those from the other two stocks. Other work (9) on Cox suggested that apples from trees on M26 rootstock were slightly more mature at picking than those from trees on MM106 and M7, but there was no evidence that this affected susceptibility to rotting, bitter pit, or breakdown during storage. Reports indicate that fruit from trees on M9 and M26 are generally larger than on MM106 (1), and larger fruit are generally less firm and have less storage potential than smaller fruit (8, 10).

The different herbicide treatments produced weed control results that were as expected. All treatments markedly reduced weed growth and hence, competition in the treated areas, particularly during the early part of the growing season. Later in the growing season, sufficient weed cover generally developed, minimized possible erosion, and helped with hardening off. Check plots which were hoed in the spring developed a similar weed recovery pattern. In no case did they develop an established sod.

The herbicides used over the 14 years of this study had no influence on tree size, accumulated yield, or yield efficiency, with no interactions with rootstock (Table 3). Crabtree and Westwood (2) also found no interaction between rootstock (M1, M4, M5, M7, M16, and seedling) and orchard management practices comparing herbicides with cultivation. A report on the first 7 years of this trial indicated that the only herbicide influence was an increase in trunk circumference and tree spread associated with Cytrol (changed to Roundup in 1973) combined with Diuron and the combination of Paraquat and Sinbar. The differences at that time were not great and disappeared in the last 7 years of the study.

Although not drastically significant, trunk circumference measurements from all herbicide treatments were larger than the control. This pattern is likely a carry-over of the significant increase in growth observed on the young trees (3) present with

TABLE 4.—Influence of Herbicide Treatments Averaged Over Rootstocks on Tree Growth and Cropping of Blaxtayman Apple Trees at the Jackson Branch, OARDC.

Herbicide Treatment	Tree Size 1981			Accumulated Yield		Weed Rating†
	Trunk Circumference (cm)	Height (m)	Spread (m)	lb/Tree	lb/cm²	
Check—Hand Hoed	51.3	4.3	4.7	1054	49.8	2.5
Casoron 46 + Paraquat + X77*	54.2	4.9	5.5	829	38.4	1.7
Simazine 4G-80W	54.4	5.0	5.5	873	39.2	2.5
Paraquat + X77 + Simazine 80W	55.5	4.8	5.2	874	38.3	4.0
Paraquat + X77 + Diuron 80W	55.0	4.7	5.5	824	41.8	3.5
Diuron 80W + Sinbar 80W	55.7	4.4	5.2	914	41.3	6.0
Roundup + Diuron 80W	59.1	4.7	5.2	1024	40.9	2.5
Sinbar 80W	59.4	4.9	5.2	1012	38.9	2.5

*Rates of chemicals: Casoron, 150 lb/a; Paraquat, 2 qt/a; X77, 8 oz/a; Simazine 4G-80W, 4 lb/a; Diuron 80W, 4 lb/a; Sinbar 80w, 4 lb/a.

†Weed rating: 0 = no bare soil; 10 = 100% bare soil; rated Oct. 21, 1980.

all herbicide treatments. The rating of weed growth indicates that Diuron + Sinbar and Paraquat + Simazine gave slightly better weed control than other treatments. It is indeed fortunate that long-term herbicide use had no adverse effects on any of the rootstocks in this study and a number of herbicide programs could be used in future plantings of these stocks.

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Tree Performance and Yield Efficiency of Several Apple Cultivars on M9 and M9 Interstems[1]

D. C. FERREE[2]

INTRODUCTION

Increased production costs and land values coupled with dwindling labor supplies have encouraged fruit growers to seek improved efficiency and to increase production on existing land. Previous studies in Ohio (2) have shown the efficiency of closely planted trees of Golden Delicious on M9 and M9 interstems.

The present study was divided into two segments—the M9-high density systems trial and the M9-interstem planting. The high density systems trial was initiated to test the performance of four cultivars on M9 in three supported management systems at spacings that would accommodate conventional orchard equipment. The M9-interstem study was an attempt to produce small free-standing trees and evaluate the performance of three cultivars with M9 interstem for dwarfing on four rootstocks. The length of interstem was also varied on seedling rootstock.

MATERIALS AND METHODS

The study was conducted at the Mahoning County Branch at Canfield, Ohio. The trees were produced at OARDC and planted in 1974 on a Canfield silt loam soil and received conventional management practices. Pesticide applications did not include sprays for fireblight control. Golden Delicious, Redchief Delicious, Jonathan, and Melrose on M9 were planted in north-south rows in the following management systems: 1) staked—the trees were spaced 3.1 x 6.2 m (10 x 20 ft) supported individually by 1.2 m (4 ft) wooden posts and trained to a central leader using clothespins and limb spreaders; 2) trellis—the trees were spaced 2.5 x 4.3 m (8 x 14 ft) supported by a four-wire trellis with the top wire 1.83 m (6 ft) and trained as oblique palmettes; 3) slender spindle—the trees were spaced 1.5 x 4.9 m (5 x 16 ft) supported individually by wooden posts (1.83 m protruding) and trained to the spindle system by renewal pruning and tying the leader to the post. The systems were arranged as randomized complete blocks with four replications of a 15 m row of the staked and trellis systems and (due to the close spacing) a 7.5 m row of the slender spindle, giving five to six trees of each cultivar per system in each replication.

The interstem planting was established in an adjacent block with trees produced by double grafting and planted in a nursery for 1 year. Tree size was very small at planting in 1974. Golden Delicious, Sturdeespur Delicious, and Redchief Delicious were grafted to a 15.2 cm (6 inch) M9 interstem and grafted to the following rootstocks: apple seedling, M7, MM106, and MM111. Two additional treatments consisted of Redchief Delicious on apple seedling with a 7.6 cm (3 inch) and 30.5 cm (12 inch) interstem of M9. The trees were planted with the entire M9 interstem exposed above the soil. The trees were set 2.8 x 6.2 m (9 x 20 ft) in a randomized block design with five replications, with two trees of each combination per replication.

RESULTS AND DISCUSSION

The first crop of record on the M9 trees in the high density systems occurred when the trees were 4 years old, with Golden Delicious generally producing more fruit than the other cultivars (Fig. 1). Trees of all cultivars on the staked system generally had lower yields than the same cultivar in the more intensive systems. The exceptions to this trend were Jonathan and Redchief Delicious in 1977, the first year of production.

Production of Golden Delicious, Melrose, and Redchief Delicious in the trellis and slender spindle systems were very similar each year reported. This 4-year trend is particularly significant because it shows the efficiency of the trellis system which had fewer trees (156 trees per acre) than the spindle system. Ferree (2) identified the efficiency of Golden Delicious in the trellis system compared to the slender spindle in a Wooster study, and indicated as a possible reason for this the containment pruning required for the slender spindle trees. However, the trees in this study were on a soil which produced less growth and containment pruning was not necessary.

The wide between-row spacing used in this study to accommodate conventional orchard equipment significantly reduced yields compared to yields where between-row spacing was adjusted to tree size (2) and management system rather than equipment. In the Wooster planting (2), the between-row spacings for trellis and slender spindle were 12 and 10 feet, re-

[1]The author expresses appreciation to Clifford A. Morrison of the Mahoning County Branch for orchard care and to John C. Schmid for technical assistance.

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TABLE 1.—Trunk Circumference, Accumulated Yield, and Yield Efficiency Through 1980 of Four Cultivars on M9 in Three Orchard Management Systems Planted in 1974 at the OARDC Mahoning County Branch, Canfield.

Cultivar	Trunk Circumference	Accumulated Yield lb/Tree				Accumulated Yield/Trunk Cross-sectional Area lb/cm²				Accumulated Yield/Acre bu/acre			
		Staked	Trellis	Spindle	Av.	Staked	Trellis	Spindle	Av.	Staked	Trellis	Spindle	Av.
Golden Delicious	13.6a*	150.5	144.3	99.5	131.4a	57.8	57.3	46.4	53.8a	863	1541	1457	1287a
Melrose	11.8a	68.3	97.7	67.4	77.8b	36.7	33.7	44.6	38.3b	337	1179	1057	871c
Jonathan	7.4b	82.4	80.2	50.2	70.9b	27.7	28.6	17.5	24.6c	556	980	1254	930b
Redchief Delicious	7.8b	40.4	62.7	51.8	51.6c	28.2	42.2	38.1	36.2b	190	717	749	552d
LSD .05			27.2				12.0				227		
Average		85.4a	96.2a	67.2b		37.6a	40.4a	36.7a		496b	1104a	1129a	

*Means with a letter in common are not different, LSD .05.

TABLE 2.—Performance of Redchief Delicious Trees with Three Interstem Lengths on Apple Seedling Rootstock Planted in 1974 at the OARDC Mahoning County Branch, Canfield.

Interstem Length (cm)	Trunk Circumference				Number of Rootsuckers			Yield (lb/Tree)			Accumulated Yield	
	1980 (cm)	Change (cm)										
		1977-78	1978-79	1979-80	1975	1976	1977	1978	1979	1980	lb/Tree	lb/cm² Trunk
7.6	12.3a*	5.4a	2.7a	2.0a	1.7b	3.9b	11.1b	1.7	2.2	13.5	17.3	8.6
15.2	7.7a	4.6ab	1.8ab	0.5b	3.6a	7.4ab	10.5b	2.8	6.2	10.0	18.9	14.0
30.5	6.8a	3.0b	0.7b	0.6b	4.6a	9.0a	19.1a	0.9	3.6	3.7	8.3	11.0

*Means with a letter in common are not different, LSD .05.

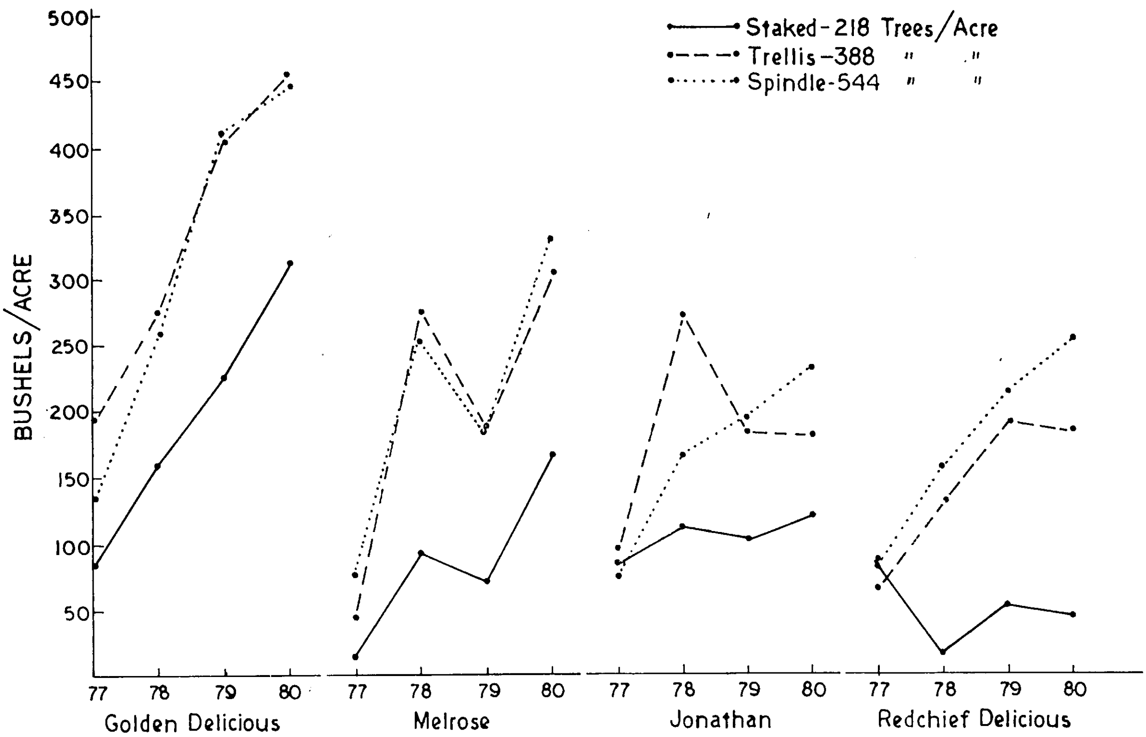

FIG. 1.—Yield of four cultivars on M9 rootstock in three training systems established in 1974 at the OARDC Mahoning County Branch, Canfield.

spectively, while in the Mahoning County planting these distances were 14 and 16 feet, respectively.

The fifth and sixth production years in both plantings were not influenced by frost, although they occurred in different years. The closely planted trees in the Wooster trellis planting out-yielded the Mahoning planting 43% and 74% in the fifth and sixth year, respectively. The same figures for the slender spindle comparison were 55% and 75% for the fifth and sixth years of production. Although the difference in year of planting and different weather conditions between the years play a role in these dramatic differences, the most important factor was the wasted area between rows needed for large equipment. The comparison emphasizes the importance of choosing carefully the planting distance and adapting it to the soil, cultivar, and rootstock so that minimum space is wasted.

The efficiency of the trellis trees is further emphasized by the higher accumulated yield per tree shown by all cultivars except Redchief Delicious (Table 1). Tree size as indicated by trunk circumference was not different between trellis and spindle trees; thus, the difference in yield per tree must be due to a light penetration or other efficiency created by the training system.

It is not understood why this efficiency was not reflected in the yield per trunk cross-sectional area measurements. Golden Delicious and Melrose trees were larger than the other cultivars. Golden Delicious out-produced all cultivars and had the greatest production efficiency as indicated by yield per trunk cross-section. Redchief Delicious had the lowest yield per tree. However, Jonathan had the lowest yield per trunk cross-section.

In a comparison of interstem lengths of 7.6 cm (3 inch), 15.2 cm (6 inch), and 30.5 cm (12 inch), a trend was evident for smaller tree size as interstem length increased (Table 2). The decrease in tree size with increasing interstem length has been reported in previous studies (1, 4). Data on the relative growth rate as indicated by the change in trunk circumference from year to year indicate that slower growth occurs each year as interstem length is increased over the fourth through the seventh year after planting. As interstem length was increased, the number of rootsuckers produced also increased. The larger trees (shorter interstems) produced more fruit but no difference in efficiency was apparent as judged by yield per unit trunk cross-section.

The differences in interstem tree size created by the four rootstocks tested was not great, but trees on M7 tended to be smaller than on other rootstocks (Table 3). Apple seedling and M7 produced many more rootsuckers than either MM106 or MM111 and this would be a primary reason not to recommend

TABLE 3.—Performance of M9 (6-inch) Interstem Apple Trees Comparing Three Cultivars and Four Rootstocks in a Planting Established in 1974 at the OARDC Mahoning County Branch, Canfield.

	Trunk Circumference		Rootsuckers/Tree			Yield (lb/Tree)			Accumulated Yield 1978-80	
	1980 cm	Change 1979-80	1975	1976	1977	1978	1979	1980	lb/Tree	lb/cm² Trunk Area
Rootstock										
Apple Seedling	11.4ab*	1.49a	4.5a	9.8a	13.0b	10.6b	17.6b	27.7b	55.9b	22.7b
M7	9.7b	0.47b	7.0a	10.4a	19.1a	10.2b	15.3b	21.5b	47.0b	16.4b
MM106	11.5ab	0.69ab	0.7b	1.1b	3.9c	19.9a	32.3a	38.7ab	90.9a	33.9a
MM111	14.5a	1.32ab	1.2b	1.5b	3.5c	18.1a	33.7a	52.0a	103.8a	32.9a
Cultivar										
Golden Delicious	16.5a	1.48a	2.5a	3.5b	5.8b	37.0a	57.4a	74.4a	168.8a	38.0a
Sturdeespur	10.4b	0.93ab	4.5a	7.1a	14.4a	4.3b	10.9b	20.4b	35.6b	27.0b
Redchief	8.5b	0.56b	3.2a	6.6a	9.4ab	2.7b	6.0b	10.0b	18.7b	14.5c

*Main effect means with a letter in common are not different, LSD .05.

seedling and M7 as rootstocks for interstem trees. Yield per tree and yield efficiency were also higher on MM106 and MM111, making them the preferred stocks for interstem trees. Since there was not a significant difference between these two in tree size or yield efficiency, MM111 would be the recommended stock because it is less susceptible to losses to the collar rot winter injury complex than MM106.

Golden Delicious resulted in the largest trees and continued to have the greatest change in trunk circumference (Table 3). The Golden Delicious trees in this trial were nearly ideal in size and all operations could be accomplished from the ground. The yield at 7 years of age at the planted spacing was 428 bu/acre; however, the trees could have been planted closer (8 x 16 ft) without a potential crowding problem, giving a projected yield of 600 bu/acre.

Sturdeespur and Redchief Delicious trees never achieved a desirable size and would not have been considered commercial trees. Double grafting resulted in small tree size at planting and the additional decrease in growth potential due to the spur habit of these cultivars was considered the main cause of the undesirable tree size. Poor interstem tree quality due to double grafting and allowing only 1 year in the nursery has also been reported in other studies (3).

Desirable tree size has been achieved with Sturdeespur on M9 interstem trees in other plantings when vigorous nursery trees were planted. Thus, the importance of vigorous nursery stock is emphasized when dwarfing interstems and spur habit cultivars are used.

Although the life of this planting was too short to make long term judgments, these data suggest that Redchief Delicious trees were 19% smaller than Sturdeespur Delicious trees and had a slower rate of growth (change in trunk circumference) (Table 3). Redchief Delicious also appeared to have lower yields per tree and a lower production efficiency. Although most of these differences were not statistically significant in this study, the trend was rather consistent and should be evaluated further in longer term studies.

Golden Delicious interstems were particularly productive on MM111 as judged both by accumulated yield and yield efficiency (Table 4). The least productive rootstock for M9 interstems of Golden Delicious was M7. There was little difference in the production or yield efficiency of the other cultivar-rootstock combinations of these interstem trees.

TABLE 4.—Accumulated Yield (1974-1978) and Yield Efficiency of Three Cultivars with M9 (6-inch) Interstems on Four Rootstocks at the OARDC Mahoning County Branch, Canfield.

	Accumulated Yield/Tree (lb)			Accumulated Yield/Trunk Cross-section (lb/cm²)		
Rootstock	Golden Delicious	Sturdeespur Delicious	Redchief Delicious	Golden Delicious	Sturdeespur Delicious	Redchief Delicious
Apple Seedling	131.4	23.2	13.1	40.6	18.5	9.2
M7	108.3	22.5	10.3	23.8	17.5	7.9
MM106	197.9	58.9	15.9	35.9	47.0	18.7
MM111	237.8	38.0	35.5	51.8	24.9	22.1
	LSD .05 = 45.0			LSD .05 = 15.8		

In 1979, Ohio experienced a severe epidemic of fireblight and these plantings suffered very severe tree losses which are shown in the article on page 20. The early production and efficiency of trees on M9 and M9 interstems offer growers the best opportunity to get early returns from expensive land. However, the risk of severe tree loss due to fireblight must be recognized and every effort must be made to control the disease on young trees.

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Chemical Induction of Lateral Shoots on Young Apple Trees[1]

S. C. MYERS and D. C. FERREE[2]

INTRODUCTION

Several European studies have demonstrated the desirability of planting well branched or feathered maiden trees (6, 10). Feathered trees have shown particular promise in modern high density plantings which depend on early cropping to control tree growth and offset high initial investments (4, 6, 10). Early cropping and yield were positively correlated with the initial number of feathers (branches) on newly planted trees (6, 8). Feathers provided sites for early development of flower buds (10) and resulted in a 39% increase in cropping in the second year of growth as compared to trees that were unfeathered at planting (6).

Although historically orchards in this country have been planted with lower tree density per acre, utilizing unbranched 1-year whips as planting material, the planting trend in recent years has been more intensive. This planting trend stimulated research to see if feathered trees could be developed with Ohio cultivars and if these trees would prove beneficial under Ohio conditions.

Feathers on newly planted trees can be beneficial in tree development, especially on cultivars that exhibit bare wood, minimal branching, and poor crotch angles (5). In a comparison of feathered and non-feathered trees, feathered trees exhibited increased shoot numbers, total shoot growth, trunk circumference, and total tree weight (5). Preston (5) found that the crotch angles of primary branches on feathered trees were wider and resulted in a strong primary scaffold system.

Feather production on apple trees has been induced with growth regulators such as 6-benzylamino purine (BA), ABG-3001 [BA + gibberellins A4+7 (GA4+7)], M & B 25105, mixtures of C_6 to C_{12} fatty acid esters, and 5-chloro-3-methyl-4-nitro-1H-pyrazole (AGB-3030), which overcome or inhibit apical dominance (1, 2, 3, 4, 6). Chemical induction is more desirable than pruning to induce feathering as pruning results in a small number of upright shoots with narrow crotch angles (4). Ideally, chemical feathering agents which inhibit but do not kill the terminal bud temporarily slow terminal growth, induce lateral bud break, and result in weak and wide angle lateral shoots (4, 6).

Since several of the branching chemicals used in Europe will not be available in the U. S., the present study was conducted to evaluate several potentially available materials for their influence on feathering. The study was made with container grown apple trees and was divided into three experiments: 1) the influence of a surfactant on the efficacy of spray applied chemicals; 2) the influence of lateral bud age on response to growth regulators; 3) to study development of lateral shoots following treatment.

MATERIALS AND METHODS

Experiment I

'Red Prince Delicious'/M26 trees were grown in a greenhouse during early spring and trained to a single shoot in 2.9 liter pots containing a medium of 3 loam soil: 1 peat:1 perlite (by volume). All trees received 15 g of slow release fertilizer (14N-6P-11.6 K) and an additional 1.2 liter of 100 g/ml of 20.0N-8.7P-16.6K fertilizer. Trees were selected for uniformity and grouped according to height. A randomized complete block design with five single tree replications was used. Apple trees averaging 57.0 cm in height were treated with foliar sprays of 500 ppm BA + 500 ppm GA4+7, or 500 ppm BA + 500 ppm GA4+1000 ppm daminozide, and compared to an unsprayed control. Treatments were applied to entire trees to runoff with a hand sprayer. Tree height and node diameter were measured 28 days after treatment when it was apparent no lateral shoots were induced.

Treatments noted in Experiment I were reapplied 28 days later to the same trees, averaging 92.0 cm in height and still actively growing. A 1.0% Tween 20 surfactant rate (by volume) was added to all treatments with exception of the control. The number of lateral shoots, total lateral shoot growth, location of laterals, and tree height were measured after shoot growth had stopped.

Experiment II

Trees averaging 57.0 cm in height were treated with 1000 ppm BA, 1000 ppm BA + 1000 ppm GA4 +7, 100 ppm BA + 100 ppm GA4+7, or 10 ppm BA + 10 ppm GA4+7. Treatments were applied in a lanolin paste to individual lateral buds beginning with the sixth bud above the graft union. Fifteen lateral buds on each tree were treated.

[1]Appreciation is expressed to Abbott Laboratories for the chemicals used in these studies and to John C. Schmid for technical assistance.

[2]Assistant Professor, Dept. of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg (formerly Graduate Research Associate, Dept. of Horticulture, Ohio Agricultural Research and Development Center and The Ohio State University); and Professor, Dept. of Horticulture. This work was part of the Ph.D. dissertation of the senior author at The Ohio State University.

TABLE 1.—Influence of Foliar Sprays of Selected Feathering Chemicals on Height, Node Diameter and Lateral Shoot Number, and Length of 'Red Prince Delicious'/M26.*

Treatment	Concentration (ppm)	Initial Application: Final Height (cm)	Initial Application: Change in Height (cm)	Initial Application: Node Diameter (cm)	Reapplication Plus Tween†: Change in Height (cm)	Reapplication Plus Tween†: Total Lateral Shoot Growth (cm)	Reapplication Plus Tween†: Number Laterals	Reapplication Plus Tween†: Average Length per Lateral
Control		105.0a	47.8a	0.74b	13.6	4.0c	2.4b	0.2c
BA + GA4 + 7	500 + 500	89.7b	33.2b	0.89a	12.4	73.2a	8.2a	8.9a
BA + GA4 + 7 + daminozide	500 + 500 + 1000	81.1b	23.4c	0.85a	9.0	34.6b	9.8a	3.5b

*Mean separation within columns by Duncan's multiple range test, 5% level.
†1.0% Tween 20 surfactant added to all treatments except control.

Experiment III

MM106 apple trees, actively growing, were trained to a single shoot in 2.9 liter pots containing a medium of 2 peat:1 vermiculite:1 perlite with needed fertilizer added. Trees averaged 65.0 cm in height when the following foliar treatments were applied: untreated (control), 500 ppm BA, 500 ppm BA + 500 ppm GA4+7, or 500 ppm BA + 500 ppm GA4+7 + 1000 ppm AGB-3030. A 1.0% Tween 20 surfactant rate (by volume) was used in all treatments with exception of the control.

RESULTS

Experiment I

Lateral bud break was not induced by any of the spray treatments; however, terminal growth was reduced by BA + GA4+7 (Table 1). The combination of daminozide with BA + GA4+7 further reduced terminal growth. Stem diameter was not influenced by any of the treatments, but growth regulator treatments caused a swelling of the nodal areas as indicated by increase in node diameter.

The reapplication of treatments, with addition of surfactant, had little effect on terminal growth as indicated by change in height (Table 1). BA + GA4+7 induced laterals and resulted in an increase in total growth of laterals, number, and average shoot length compared to control trees. The addition of daminozide with BA + GA4+7 decreased total lateral growth and average shoot length.

Experiment II

Lateral buds, located on the basal half of the trees, were induced to grow only by BA and BA + GA4+7 in lanolin at concentrations of 1000 ppm (Table 2). There were no differences between these two treatments in lateral length or lateral height at various locations. Average shoot length was 1.70 cm; thus, growth regulators induced lateral bud break but did not maintain continued extension growth.

Experiment III

BA + GA4+7 and BA + GA4+7 + AGB 3030 reduced tree height but had no effect on total growth as compared to control trees (Table 3). However, BA alone increased total growth of trees. Growth regulator treatments induced equal numbers of lateral shoots. However, most of the lateral shoots induced by BA + GA4+7 and BA + GA4 +7 +AGB 3030 were 5 cm in length, while 43% of the lateral shoots induced by BA were 5 cm in length. The addition of AGB-3030 did not influence the effect of BA + GA in inducing lateral shoots.

Shoot development of the uppermost lateral shoot induced by the growth regulators was at a

TABLE 2.—The Influence of Selected Feathering Chemicals in a Lanolin Paste Applied to Individual Buds on the Length of Shoots Developing from Buds of 'Red Prince Delicious'/M26.*

Treatment	Concentration (ppm)	Average Lateral Shoot Length (cm)	Average Lateral Shoot Length (cm), Bud Number from Scion Union: 6-10	11-15	16-20
Control		0b	0b	0b	0b
BA	1000	1.87a	1.52a	1.45a	2.62a
BA + GA4+7	1000 +1000	1.53a	1.26a	1.54a	1.81a
BA + GA4+7	100 + 100	0b	0b	0b	0b
BA + GA4+7	10 +10	0b	0b	0b	0b

*Mean separation within columns by Duncan's multiple range test, 5% level.

TABLE 3.—Influence of Foliar Sprays of Selected Feathering Chemicals on Tree Height and Total Growth, Length and Location of Lateral Shoots of MM106.*

Treatment†	Concentration (ppm)	Total Height (cm)	Total Growth (cm)	Number of Lateral Shoots			Location of Lateral from Base		Average Length per Lateral (cm)
				5cm	5cm	Total	Upper	Lower	
Control		109.8a	109.8b	0c	0b	0			0c
BA	500	104.3a	163.1a	5.9b	4.5a	10.4	65.8	42.9	5.65a
BA + GA4+7	500 + 500	94.9b	118.3b	10.1a	1.1b	11.2	68.0	43.9	2.15b
BA + GA4+7 + AGB 3030‡	500 + 500 + 1000	92.0b	105.1b	10.3a	0.6b	10.9	68.6	44.8	1.18b

*Mean separation within columns by Duncan's multiple range test, 5% level.
†1.0% Tween 20 surfactant added to all treatments except control.
‡5-chloro-3-methyl-4-nitro-1H-pyrazole

height corresponding to the shoot tip at the time treatments were applied. The zone of lateral shoot induction extended from the shoot tip in a basal direction for approximately 24.0 cm. There were no differences in the crotch angles of the uppermost lateral shoots (data not included) between the growth regulator treatments.

DISCUSSION

Single applications of 100 or 500 ppm BA with 0.1% surfactant had only a slight effect in initiating lateral shoots in work by Kender and Carpenter (3). Multiple applications were required for effective response (3). These results suggest a higher concentration (1%) of surfactant can increase the effectiveness of BA, thus reducing the need for multiple applications (Table 1).

Under conditions of this experiment, BA increased total growth and average lateral shoot length compared to BA + GA4+7 (Table 3). Data of Williams and Billingsly (11) showed no difference in total shoot growth in trees treated with BA or in combination with GA4+7. The combination of BA with GA4+7 reduced total tree height, while height of BA-treated trees was not different from control trees in work by Edgerton (2). Edgerton also found no significant increase in number or length of laterals when GA4+7 was combined with BA using a 0.1% Tween 20 surfactant rate (2). Thus, the addition of GA4+7 with BA to induce lateral shoot production offers no advantage to using BA alone. The use of AGB 3030 in combination with BA + GA produced no increase in laterals compared to BA or BA + GA (Table 3).

Buds near the apex at the time of application demonstrated a maximum sensitivity to feathering agents, with sensitivity declining in a basal direction.

Growth of lateral shoots may be the result of a balance between growth regulators. Sach and Thimann (7) showed that kinetin, a cytokinin, released lateral buds but auxin was necessary for continued growth. The natural absence of lateral bud break on current season's growth may be due to suboptimal levels of cytokinins rather than supraoptima levels of auxin.

Edgerton (1) found that daminozide in combination with BA + GA4+7 not only reduced extension growth but also increased the number of lateral shoots induced. In this experiment the addition of daminozide with BA +GA4+7 resulted in a decrease in average lateral length but had no effect on lateral shoot number compared to BA + GA4+7 alone. Thus, the use of daminozide provided no benefit in the chemical induction of lateral branches.

None of the spray applications of growth regulator treatments induced any visible phytotoxic effects. However, the growth regulator treatments applied in a lanolin paste caused some bud death and leaf burn.

Unfortunately, growth regulator treatments did not induce sufficient lateral shoot growth to provide what is considered a high quality feathered tree. However, the relatively short lateral shoots induced (1 to 9 cm) were judged to have desirable crotch angles and would provide sites for shoot growth in the season following treatment. Growth regulator treatments which will induce longer lateral shoots are desired to achieve potential increases in yield and earlier bearing resulting from well-feathered trees. Studies are needed to test the efficacy of growth regulators to induce lateral shoot growth under various field conditions and with various cultivar rootstock combinations. The physiological potential of the feathered tree needs to be evaluated in less intensive plantings to evaluate its economic value.

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The Influence of Urea Sprays, Mulch, and Pruning on Apple Tree Decline[1]

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INTRODUCTION

During the past 20 years, many mature and aging orchards have been removed and replaced with trees on clonal rootstocks. It is not readily apparent, in retrospect, whether these orchards were removed because of age, tree size, declining production, or the desire to develop a more efficient production unit. However, during the early 1960's, "apple tree decline" was a serious problem of many older apple orchards in the Eastern United States. The first visible symptom of the malady was the general loss of vigor by affected trees. Trees that were affected soon became so unproductive that they were of little commercial value. In the more advanced stages of the disorder, large limbs became necrotic and death of the entire tree occurred.

Studies at the OARDC implicated nymphs of the periodical cicada (*Magicicada* spp.) and low soil pH as contributing to the condition known as apple tree decline (1, 2, 3, 4). The average soil reaction for all trees sampled in this study was pH 4.5. In the case of samples representing soil from 14 decline orchards, the pH was from 3.6 to 3.9 (2, 3). Counts of cicada nymphs in soil samples taken from 17 different orchards showed that many more nymphs were found under decline trees than under healthy trees (3, 4). Examination during detailed excavation indicated that the nymphs were feeding upon the roots and that death of the roots had occurred where heavy populations of the nymphs were encountered.

FIG. 1.—Areas and years of expected emergence of the 17-year cicada in Ohio.

A large portion of Ohio will have emerging cicada populations in 1982, 1985, and 1987 (Fig. 1). The cicada as it nears emergence and is active near the soil surface can have a very detrimental effect on apple trees. Established commercial orchards represent sizable investments in time and money. Thus, any knowledge of methods, practices, or treatments that will maintain or rejuvenate declining orchards should be put into use at this time (5).

A study was conducted during 1963 and 1966 at the Ohio Agricultural Research and Development Center to ascertain the effect of several cultural practices on decline trees, once steps had been taken to remove or correct the causal agents: cicada nymphs and low soil. The accumulated information, relating remedial cultural practices to tree response, should serve as a guide to maintain orchard damage from anticipated cicada attacks.

MATERIALS AND METHODS

In 1963, a 25-year-old Delicious apple orchard in Carroll County, which was showing serious symptoms of tree decline, was selected for this study. Prior to the establishment of the cultural treatments, 3 plots of 16 uniformly declining trees each were limed using 6 tons of agricultural limestone per acre. The lime was disked into the soil beneath half of the limed trees to determine if a pH change would occur more quickly.

For cicada nymph control, half of the test trees in the orchard were treated with soil injections of the insecticide carbaryl (Sevin) at the rate of 2 lb of 50 WP carbaryl per tree. Two lb of carbaryl were mixed with 100 gal of water and the material was applied by making 50 soil injections to a depth of 18 inches beneath each treated tree. The 17-year emergence cycle for the periodical cicada occurred in the spring of 1965. Any nymphs not killed by the soil injection treatment or nymphs under trees not

[1]The authors gratefully acknowledge the assistance and cooperation of George Downes Orchards, Magnolia, Ohio.
[2]Professor of Horticulture and Acting Director.

treated with carbaryl were destroyed by appropriate pesticide sprays as they emerged as adults.

Cultural treatments used in the study were selected to either compensate for reduced tree root growth or make the soil environment more favorable for growth of new roots. Treatments involved individual as well as combinations of: 1) foliar urea nitrogen sprays to supplement nitrogen absorption by the roots, 2) severe pruning to adjust the size of the top of the tree to the reduced size of the tree's root system, and 3) mulch to stimulate new root formation and thereby increase both nutrient and water absorption by the tree.

Four foliage sprays of urea applied at the rate of 6 lb per 100 gal of water were made in 1963, 1964, 1965, and 1966 at weekly intervals starting at petalfall. Each mulch-treated tree received eight bales of wheat straw spread beneath the branches in early spring each year. Severe pruning involved some "heading back" during the first year and removing at that time approximately three times as much wood as the grower normally removed. Severely pruned trees were pruned normally after 1963. Control trees were trees that did not receive the special cultural treatments and were maintained under routine orchard practices.

The response of the trees to different cultural treatments was ascertained by taking leaf samples in early August for leaf analysis and terminal shoot growth as a measurement of tree vigor. Soil samples were taken in 1965 and 1966 at 6-inch and 12-inch depths beneath treatment trees to determine if soil pH changed following application of lime. Yield data were only obtained in 1964 and 1965 as late spring freezes removed most of the 1963 and 1966 crop.

RESULTS AND DISCUSSION

Soil pH and Cicada Nymph Population

The effect of the two pre-treatment practices, killing cicada nymphs with Sevin and changing soil pH, were not encouraging. Digging beneath the insecticide treated trees, several months after application, revealed a relatively low percent kill of cicada nymphs (less than 25%).

Soil tests in March 1965 and 1966 from incorporated and non-incorporated lime-treated trees indicated no appreciable change in soil pH 6 to 12 inches below the surface (Table 1). The data indicate there was a slight increase in soil pH under non-incorporated trees at the shallow, 0-6 inch, depth. However, the importance of this change could be questionable since most of the tree's roots were considered to be below the 6-inch depth.

Nutritional Status of Trees

Four-year results of foliar analysis indicated that cultural treatments applied individually (urea, mulch, or severe pruning) did not substantially change the nitrogen content of the leaves until the third year, 1965 (Table 2). Severe pruning never did increase the foliar N content. Trees sprayed with urea were much greener throughout the growing season and it was somewhat surprising that foliar N content was not greater for the first 2 years than unsprayed control trees. The last 2 years of the experiment, 1965 and 1966, both the urea and mulch treatments increased the nitrogen content of the foliage. All combinations of the cultural treatments increased the leaf nitrogen in 3 of the 4 years applied.

The only other foliar elements that were significantly affected by the cultural treatments were phosphorus, magnesium, and manganese. Urea used alone or in combination with other cultural treatments tended to reduce the phosphorus content of the foliage. Magnesium in the foliage was increased by the combination of mulch plus urea treatment. Manganese was significantly increased in the foliage when mulch was used alone or in combination with other cultural treatments.

Terminal Shoot Growth

During 1963 and 1964, only the trees receiving the combination treatments of four urea sprays plus mulch plus severe pruning showed a significant increase in vigor as measured by terminal shoot growth

TABLE 1.—Influence of Lime and Cultivation on Soil pH—6 Tons of Lime Applied per Acre in March 1963.

Treatments	Soil Depth (inches)	pH of Soil Samples March 1965	pH of Soil Samples March 1966
Limed—Incorporated	0-6	5.1	5.2
	6-12	5.0	5.1
Limed—Non-incorporated	0-6	5.3	5.5
	6-12	5.0	5.1
Not Limed	0-6	4.9	5.0
	6-12	4.9	4.9

TABLE 2.—Influence of Cultural Treatments on Essential Mineral Element Content of Leaves from Decline Trees.

	Percent Dry Weight								Parts per Million				
	Nitrogen†				3-Year Average (1964 through 1966)								
Treatments	1963	1964	1965	1966	K	P	Ca	Mg	Mn	Fe	B	Cu	Al
Control	2.12	2.25	2.01	2.19	1.94	0.245	1.19	0.281	77	124	35	11	197
Urea	2.24	2.38	2.20*	2.54**	1.90	0.185**	1.11	0.304	72	136	32	15	231
Mulch	2.19	2.42	2.15*	2.62**	1.89	0.231	1.16	0.266	103*	117	32	10	187
Severe Pruning	2.28	2.23	2.08	2.28	1.87	0.250	1.07	0.278	77	119	36	11	198
Urea + Mulch	2.41*	2.45*	2.30**	2.70**	1.83	0.206*	1.23	0.337**	124**	124	34	10	202
Urea + Severe Pruning	2.38*	2.37	2.31**	2.58**	1.86	0.216	1.22	0.303	81	125	33	10	218
Mulch + Severe Pruning	2.40*	2.38	2.31**	2.68**	1.91	0.226	1.04	0.279	137**	108	33	10	189
Urea + Mulch + Severe Pruning	2.44*	2.35	2.37**	2.75**	1.82	0.240*	1.11	0.296	90*	141	30	10	208

*Significantly different from control treatment at .05 level.
**Significantly different from control treatment at .01 level.
†Nitrogen sufficiency range = 1.8-2.4%.

(Table 3). However, by 1965 the only spray treatment containing urea that failed to produce an increase in terminal shoot growth was the combination urea sprays with severe pruning. During the year following cicada emergence (1966), trees from all treatments increased in vigor as compared to the previous year. This can be attributed not only to the reduced stress from the cicada, but also from a reduced crop. However, the valuable observation to be made is that treatment differences were still maintained from the previous year (1965).

Total Yield of Fruit

Yields were severely reduced in 1963 and 1966. Therefore, total yield of fruit per tree has been reported only for 1964 and 1965 (Table 4). Individual cultural treatments of both urea sprays and mulch increased yield in 1964. The three treatment combinations of urea sprays plus mulch plus severe pruning also resulted in a yield increase. Severe pruning in 1963 but normal pruning in 1964-66 resulted in a depressed yield. In 1965 application of urea reduced production while the treatment combinations of urea sprays plus severe pruning and mulch plus severe pruning increased production.

It is obvious that alternate bearing factors are also at work here. If production had proceeded in a normal manner during all 4 years, this picture may have been more clear. However, it can be stated that yield per tree as an average (1964-65) was increased by urea spray treatment alone and with the addition of mulch plus severe pruning. Severe pruning alone also reduced yield.

SUMMARY AND CONCLUSIONS

Results from this study warrant the following conclusions:

- The best single cultural treatment considering both visual appearance of the trees and yields was the application of four urea sprays at weekly intervals beginning at the petal-fall period of fruit development.
- The best combination of cultural treatments was urea N spray + mulch + severe pruning. Vegetative shoot growth was markedly improved over control trees and average yields for the 2-year period were increased more from this treatment than any of the others.
- Decline trees should not be pruned severely unless application of urea N and mulch are also made. Severe pruning alone drastically reduced yields and did not improve vegetative growth.
- Heavy application of agricultural lime (6 tons per acre) failed to appreciably change the pH

TABLE 3.—Influence of Cultural Treatments on Terminal Shoot Growth of Declining Apple Trees.

Cultural Treatments	Terminal Shoot Growth (in)			
	1963	1964	1965	1966
Control	1.7	1.2	2.7	6.2
Urea N Sprays	2.1	2.0	4.4*	8.7*
Mulch	1.6	1.4	3.8	7.6
Severe Pruning	2.6	2.8	3.8	6.6
Urea Sprays + Mulch	1.7	1.4	5.2*	10.3**
Urea Sprays + Severe Pruning	1.9	2.0	3.9	6.2
Mulch + Severe Pruning	2.3	2.4	6.5**	8.2*
Urea Sprays + Mulch + Severe Pruning	4.3*	4.5*	6.7**	9.0**

*Significantly different from the control treatment at the .05 level.
**Significantly different from the control treatment at the .01 level.

TABLE 4.—Influence of Cultural Treatments on Total Yield of Fruit of Declining Apple Trees.

Cultural Treatments	Yield (bu/Tree)		
	1964	1965	Average
Control	9.3	7.3	8.3
Urea N Sprays	16.7**	4.0*	10.3*
Mulch	12.5*	5.3	8.9
Severe Pruning	4.2**	6.4	5.3*
Urea Sprays + Mulch	10.4	6.0	8.2
Urea Sprays + Severe Pruning	7.7	10.5*	9.1
Mulch + Severe Pruning	7.8	10.8*	9.3
Urea Sprays + Mulch + Severe Pruning	12.5*	9.9	11.2*

*Significantly different from the control treatment at the .05 level.
**Significantly different from the control treatment at the .01 level.

of the soil in an established apple orchard after a 4-year period.

- Soil injections of the insecticide carbaryl beneath decline apple trees failed to substantially reduce the cicada nymph population.

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Influence of Fireblight and Ambrosia Beetle on Several Apple Cultivars on M9 and M9 Interstems

F. R. HALL, M. A. ELLIS, and D. C. FERREE[1]

INTRODUCTION

In 1979, Ohio experienced a very severe epidemic of fireblight caused by the bacterium, *Erwinia amylovora* (Burr.). Concurrent with the occurrence of this disease was the observation that many of the dead and dying trees also had shot holes caused by a small ambrosia beetle, later identified as *Xylosandrus germanus* (Blfd.)[2]. The purpose of this study was to verify the extent of fireblight in dead and weakened trees in several types of high density apple management systems within the state and to confirm the presence of the *X. germanus* within these dead and dying apple trees.

METHODS AND MATERIALS

The major part of the study was conducted at the Mahoning County Branch, Canfield. These tree management systems were those studied by Ferree (see page 7), *i.e.,* M9 high-density system and the M9-interstem planting, both planted in 1974. The plantings included Golden Delicious, Redchief Delicious, Jonathan, and Melrose on M9 rootstock in four management systems and consisted of four replications of five to six trees of each combination. The second system was an interstem planting of Golden Delicious, Sturdeespur, and Redchief Delicious on M9 grafted to seedling, M7, MM106, and MM111 and had five replications of two trees of each combination.

Studies on these plantings were made in August 1979 and consisted of tree by tree observations for both fireblight infection and whether or not the trees had shot holes. The intensity of beetle infestation was recorded as none, less than six, or more than six holes per tree and the location of such holes. Additionally, tissue samples were taken from trees at Canfield in order to verify the presence of *E. amylovora* in the interstems and rootstocks.

In September 1979, observations and counts of tree death and shot hole densities were also recorded from two commercial apple plantings. In Union County, a 1,200 tree planting of 5-year-old dwarf Rome Beauty and Jonathan apples on C6 interstem K14 trunk stems were also examined for fireblight and beetle symptoms. In September 1979, a similar survey was conducted on a 4-year-old dwarf Rome Beauty apple planting (C6 interstems) in Erie County.

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[2]Identification provided by C. A. Triplehorn, Professor of Entomology.

RESULTS AND DISCUSSION

Generally, fireblight infections on apple occur as a blossom or twig blight and are usually not severe enough to kill the tree of most commercial cultivars. However, in this study nearly 25% of the M9 interstem trees on apple seeding, M7, and MM106 rootstock were killed when fireblight infected the interstem (Figs. 1 and 2). Only half as many trees on MM111 rootstock were killed.

The fireblight bacterium, *E. amylovora,* was isolated from infected M9 interstems and rootstocks. In some cases, it was obvious that infection occurred through rootsuckers (Fig. 3) produced by the rootstock, but in many cases rootsuckers were not the cause of the bacterium getting into the trees. The mode of entry for the bacteria into the interstem and rootstock tissues is not understood. However, it is apparent that once the bacteria enter and infection occurs, the M9 rootstock and interstem tissues are rapidly killed and the tree dies. Usually the tissues above and below the infected interstem or above the rootstock were still apparently healthy. As noted in Table 1, 35% of the M9 high density system were killed while 25% of the trees in the M9 interstem planting were killed by fireblight. A similar analysis by interstem showed a slight reduction in fireblight in trees with MM111 rootstocks (Table 1).

While examining these for symptoms of fireblight infection, shot holes caused by *X. germanus* were noted on the M9 interstem and on the M9 rootstock in the adjacent planting (Fig. 4). This beetle was first identified on grape stems brought to this country from Asia in 1932. Two generations per year were observed and the beetle feeds on a fungus cultivated in the cave-like galleries in the woody stems. Similar cave-like galleries were found in infested apple trees in this study (Figs. 5 and 6). In 1940 and 1941, Hoffman (73) and Buchanan (1, 2) reported it on elm. Beetles contaminated with Dutch elm disease were also observed to transmit the disease (1, 2). It has not been previously reported on apple.

Table 1 shows the extent of beetle infestation in the management systems trial and while total infestation approximated 54% in this block, there was little difference in the extent of infestation between management systems or cultivars. In the adjacent interstem planting, the infestation approximated 30%. A comparison between the two plantings shows that the

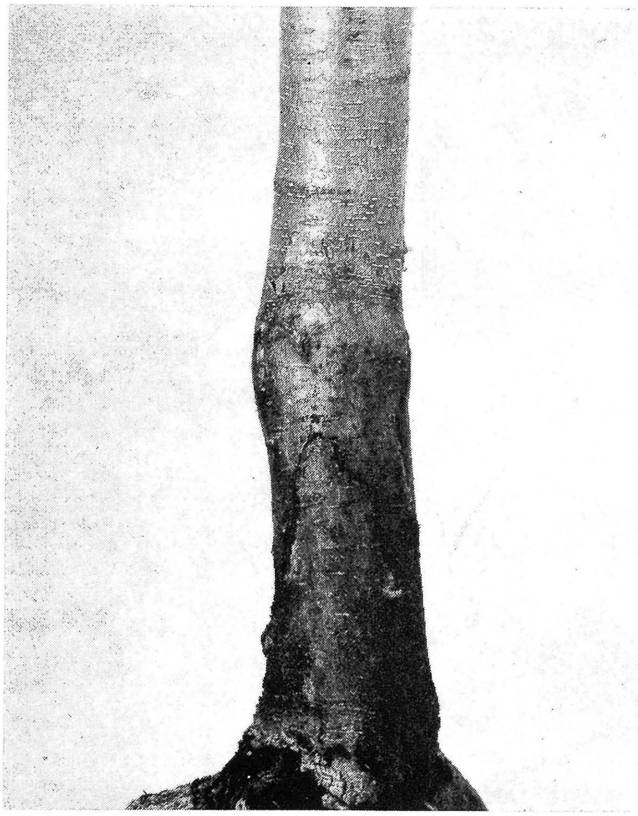

FIG. 1.—Fireblight infection on M9 interstem. Note the depressed margin of the fireblight canker.

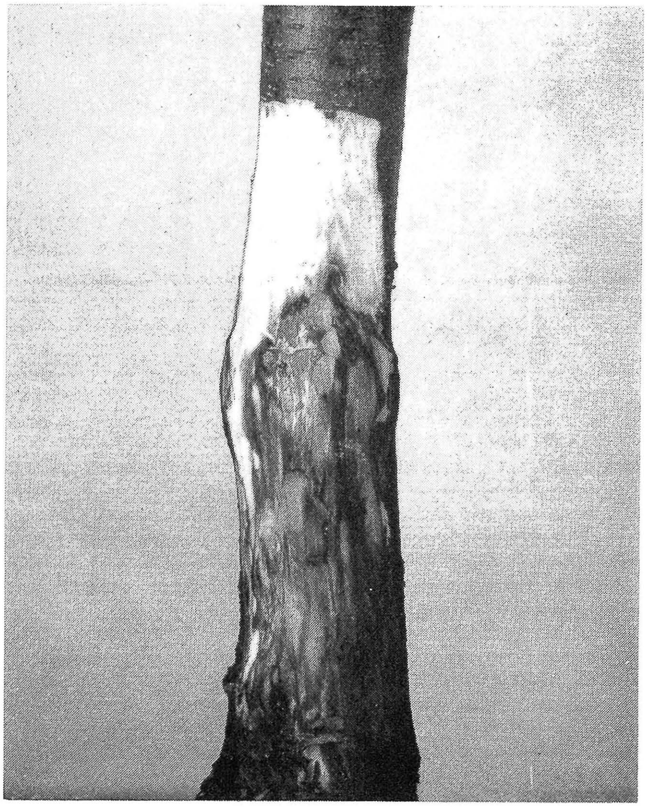

FIG. 2.—Same M9 interstem with the bark removed. Note the dead discolored wood. Wood above the interstem is still apparently healthy.

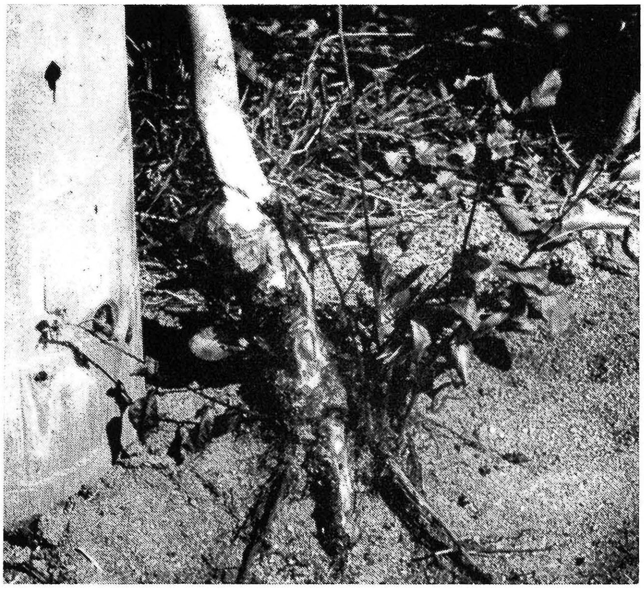

FIG. 3.—Fireblight infection on an M9 rootstock. Note the numerous suckers, many of which are infected with fireblight and probably served as a point of entry for the bacteria into the rootstock.

FIG. 4.—Shot holes in M9 interstem on apples caused by *Xylosandrus germanus.*

FIG. 5.—Cave-like galleries made by the beetle.

FIG. 6.—Adult, pupae, and larvae in the gallery.

TABLE 1.—Tree Loss in 1980 Due to Fireblight and Infestation by Ambrosia Beetle; Orchard Management System and Interstem Trials Planted in 1974, OARDC Mahoning County Branch, Canfield.

System and Cultivar	Percent Trees Killed by Fireblight	Percent Infestation with *Xylosandrus germanus*: None	Holes per Tree < 6	Holes per Tree > 6
M9-High Density System				
Golden Delicious	22	41	34	25
Melrose	30	57	20	23
Jonathan	54	36	16	48
Redchief Delicious	34	51	20	29
Average	35	46	22	31
M9-Interstem Planting				
Golden Delicious	28	70	5	25
Sturdeespur Delicious	13	68	16	16
Redchief Delicious	33	73	7	20
Average	25	70	9	20
M9-Interstem Planting				
Apple Seedling	26	74	8	18
M7	26	62	13	25
MM106	23	70	9	20
MM111	13	76	7	17
Average	22	70	9	20

larger (tree size) dwarf interstem trees had less infestation than the smaller staked, trellised, or slender spindle trees. In addition, 38% of the "apparently healthy" trees in the M9-training systems trial and 16% of the "healthy" trees in the interstem block were found to contain beetles. Contamination of these beetles by *E. amylovora* could result in an efficient means of disease dissemination. Studies on the possible transmission of *E. amylovora* by *X. germanus* need to be conducted. In both plantings, shot holes were usually found in the M9 section of the tree.

In 1979, severe fireblight outbreaks were also found in several grower plantings on dwarfing C6 interstem trees and ambrosia beetle infestations were also found in these plantings. In Union County, approximately 10% of a 1,200 tree planting of Rome Beauty and Jonathan on C6 interstem K14 trunk stem were visibly weakened and showing fireblight symptoms in the C6 interstem region (Figs. 7 and 8). The interstems were ca. 1½ feet above the soil line. Therefore, the point of entry for the bacteria was not through rootsuckers. It is not known how or where the bacteria entered the interstem. Of those weakened trees, 75% had borer holes, predominantly on the C6 interstem section. Similar infestations of the same beetle were located on 4-year-old interstem Rome Beauty trees (C6-K14) in Erie County.

It is believed that the ambrosia beetles were attracted to these already weakened apple trees. However, beetles were also found in "apparently healthy" trees. Although ambrosia beetles have historically been reported on dead, felled, or dying trees (8), they also have been observed to infect nearby apparently healthy trees (1, 2, 8). Jones (10) in 1911 traced the spread of fireblight in pear trees to wounds made by *Scolytus rugulosus* (Ratzeburg). Beetles were found in apparently healthy bark that later developed blight near the holes. In 1911, Jones (10) proved that this beetle carried and injected the bacteria. In 1915, Orton and Adams (14) found that apple tree

FIG. 7.—Fireblight infection on C6 interstem. Note that the interstem is about 1½ feet above the soil line. The bacteria could not have entered through suckers.

FIG. 8.—The same interstem with the bark removed.

borers were associated with the collar-blight form of the disease in more than 90% of the cases at the collar of the trees. In addition, Buchanan (1) speculated that *Xylosandrus germanus* could spread Dutch elm disease into healthy trees and demonstrated this potential in 1941 (2). In this study, it is most likely that the beetles were attracted to trees already stressed by the bacteria, *E. amylovora*. It is possible that the beetles added to the spread of the disease, but it is more likely the beetles were predominantly acting as secondary pests rather than primary causes of tree death.

The severe tree loss caused by fireblight resulted in the experimental plantings being pulled at the end of the 1980 season. In many cases, fireblight appeared to enter the sensitive M9 tissue through rootsuckers. Others (3, 7) have reported the sensitivity of M9 to fireblight. However, other test plantings (5) in Ohio have had fireblight strikes on numerous occasions without rootstock or interstem infection and tree loss. These trees are presently 26 years old. Norton (personal communication) has suggested that a critical period for rootstock and interstem infection may exist during the young cropping years, but older trees on M9 may be infected with fireblight in the crown (blossom or twig blight) without being killed by rootstock or interstem infections.

On land that is expensive with limited optimum fruit sites, intensive orchard systems utilizing the production efficiency of M9 still offer the fruit grower a good alternative. However, the epidemiology of rootstock and interstem infections by fireblight is not known and the potential for serious tree loss by the disease should be considered before large numbers of trees are planted. If M9 rootstock or M9 interstem trees are to be planted, a thorough fireblight prevention program should be followed with yearly sprays of streptomycin. Attention must also be given to control of rootsuckers.

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A Model Study of the Effect of Wind on Air Sprayer Jets

R. D. FOX, D. L. REICHARD and R. D. BRAZEE[1]

SUMMARY

A 1/12 scale model of an orchard air sprayer was used to measure the effect of wind and/or travel speed, simulated by a wind tunnel, on air jets produced by sprayers. At 8 inches from the sprayer-model outlet (8 ft from the simulated sprayer), wind velocities (and/or travel speeds) of 6.7 mph, blowing at 90° in relation to the direction of the air jet at the outlet, deflected the jet 15°, velocities of 10 mph deflected the jet 60°, and velocities of 15 mph deflected the jet 80° toward the rear of the sprayer. Winds blowing into the sprayer jet at 45° in relation to the direction of the air jet at the outlet deflected the jet as much as or more than winds blowing at 90°.

INTRODUCTION

Air sprayers are widely used to apply pest control agents to orchard and vegetable crops. Many times agents are applied during windy conditions and at travel speeds greater than 4 mph. The air sprayer jet (ASJ) is expected to transport and deposit the spray particles on the target. The ASJ is subject to deflection and change of velocity when it meets a prevailing wind. Further, it is deflected even in calm conditions due to the apparent crosswind effect produced by sprayer travel. Reichard *et al.* (5) [see also Brazee *et al.* (1)] reported that ASJ resultant velocities decreased with increases in sprayer travel speeds.

Brazee *et al.* (2) developed a computer model for the airflow field delivered by a sprayer. That model was used to calculate velocity profiles for ASJ's issuing into either quiescent or coflowing ambient air. Fox *et al.* (3, 4) extended that model to predict effects of crosswind and travel speed on the ASJ. They used results from experiments in which an orchard air sprayer was pulled at three travel speeds to produce deflected air jets. These deflected air velocities were measured and compared with velocities predicted by the model.

Jet deflection experiments with orchard sprayers are difficult to control because the wind varies with time and with height above the ground. Therefore, a scale model experiment was selected as the best way to precisely measure effects of crossflow on an air sprayer jet. A 1/12 scale model was used to simulate an orchard sprayer, and a wind tunnel was used to simulate wind or apparent wind caused by sprayer travel.

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The objective of this study was to measure effects of a tail-wind (coflow), a head wind (counterflow), and a crosswind (crossflow)—including travel speed effect—on the air jet produced by a 1/12 scale model of an orchard sprayer. Wind directions are given in relation to the direction of the air jet as it leaves the sprayer.

MATERIALS AND METHODS

Dimensions of the outlet radius, outlet width, and outlet air velocity for the sprayer and its 1/12 scale model are:

Factor	Scale Model Value	Simulated Sprayer Value	Scale Factor
Outlet radius	2.0 in	2 ft	12
Outlet width	0.5 in	6 in	12
Outlet air velocity	100 mph	100 mph	1
Wind tunnel velocity	0-15 mph	0-15 mph	1
Air flow rate at outlet	200 cfm	29,000 cfm	144

In the rest of this paper, model dimensions are used. To change the results to simulated sprayer scale, replace all references to inches with feet.

The sprayer model was mounted in a 2-ft by 3-ft wind tunnel. Air velocity through the tunnel could be varied by adjusting a louver. The model could be rotated about its central support; thus the sprayer jet could be directed against the tunnel airflow (counterflow), with the tunnel airflow (coflow), or at any angle across the tunnel airflow (crossflow).

In the crossflow experiments, distance from the model outlet was limited to 9 inches or less due to interference from the wind-tunnel wall. To test the effect of the tunnel wall on jet velocities, mean air velocities were measured in jets that were directed through a window in the tunnel wall. At distances greater than 1 inch from the window, mean velocities were similar with window open and closed.

A single, constant temperature, hot-film sensor was used to measure air velocities. The longitudinal axis of the sensor was mounted in the vertical direction. The sensor responded mainly to flow in the horizontal plane and only slightly to flow in the vertical plane.

Air velocity profiles were measured across the model sprayer jet in the plane of the horizontal centerline of the model sprayer. Beyond 4 inches from the sprayer outlet, some crossflows deflected the air

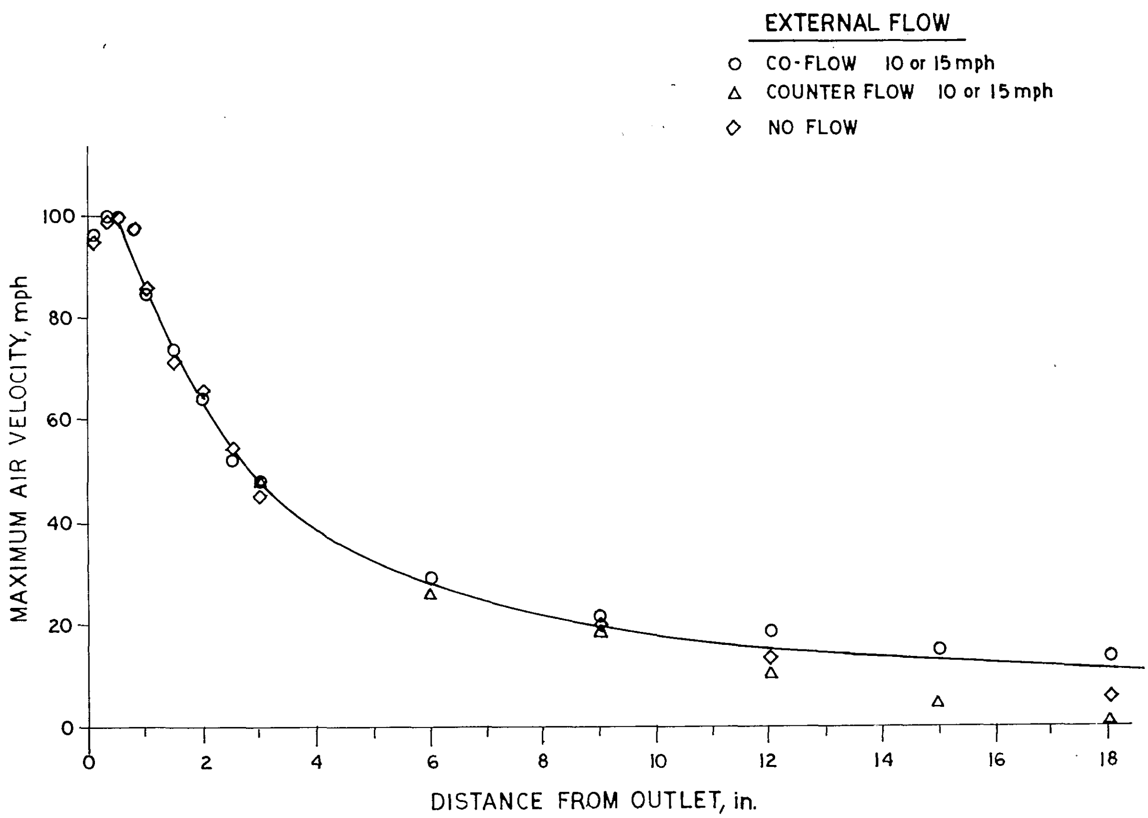

FIG. 1.—Effect of head wind and tail wind on air velocities in a model air sprayer jet at distances from 0 to 18 inches from the sprayer outlet.

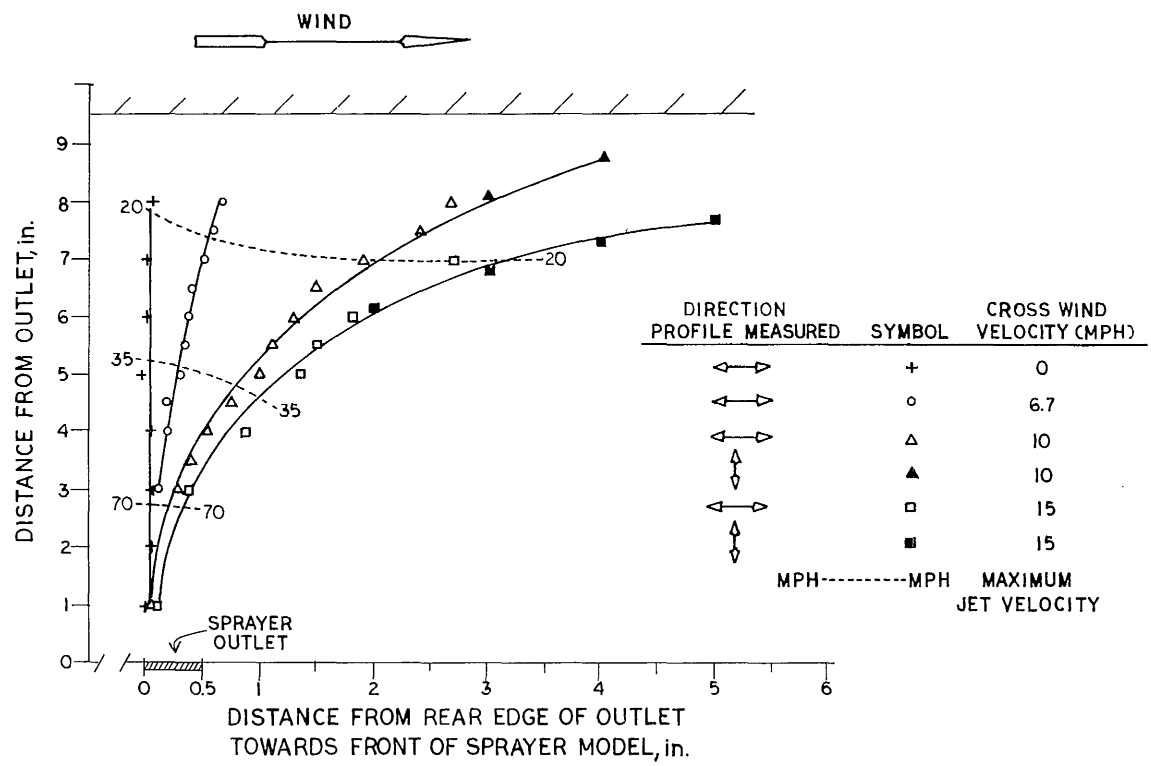

FIG. 2.—Effect of crosswind (90° angle in relation to direction of air jet at outlet) on the deflection of model sprayer jets.

jets more than 60°; in these instances, velocity profiles were measured both perpendicular to the air jet outlet and parallel to the air jet at the outlet. At most points, air velocities were measured in the model air jet both with and without air flowing through the tunnel.

RESULTS

Figure 1 is a plot of the maximum axial velocities measured at a range of distances from the outlet of the sprayer model. The solid line is the axial velocity predicted by the computer sprayer model (2). Velocities that were measured with no external flow fit this curve. These measurements indicate that the scale model can accurately simulate a real sprayer, because air velocities measured in real sprayer jets (2) were similar to those shown in Figure 1.

Although maximum jet velocities measured in crossflow experiments were not plotted in Figure 1, they agreed closely with the solid line in Figure 1, if the distance from the outlet was measured along the curved path of the jet centerline and if the crossflow velocity was less than the maximum jet velocity. Beyond 6 inches from the outlet, crossflow velocities greater than 10 mph increased the jet centerline velocity (Fig. 2).

Figure 1 illustrates the effect of coflow and counterflow on the maximum jet velocity. Within 6 inches of the outlet, there was little effect. Beyond 6 inches, air velocities were greater with coflow than with no flow and less with counterflow than with no flow.

Figure 2 is a plot of the maximum velocities measured in a jet with crossflow at 90° in relation to the direction of the jet at the outlet. A crosswind at 6.7 mph deflected the jet about 15° at 7 inches from the sprayer outlet. However, a crosswind of 10 mph deflected the jet 60°, and a wind of 15 mph deflected the jet 70°, both measured at 7 inches from the outlet.

Figure 3 is a plot of the maximum velocities measured in a jet with crossflow at 45° to the direction of the jet at the outlet. A crosswind of 6.7 mph deflected the jet about 30°, a crosswind of 10 mph deflected the jet 40° (both measured at 7 inches from the outlet), and a crosswind of 15 mph deflected the jet more than 90°.

At points where a jet was not deflected, velocity profiles measured perpendicular to the direction of the jet at the outlet were bell-shaped. At points where a jet had been deflected 60° or more, velocity

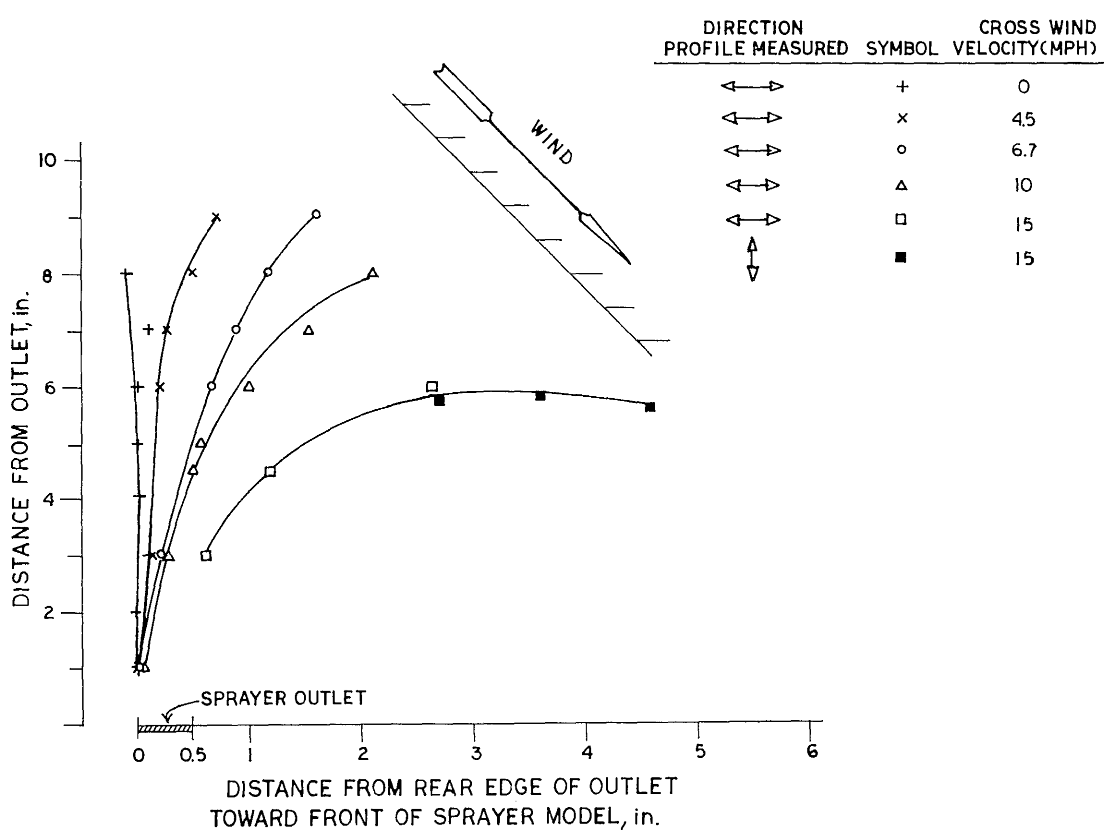

FIG. 3.—Effect of crosswind (45° angle in relation to direction of air jet at outlet) on the deflection of model sprayer jets.

profiles parallel to direction of jet at the outlet were also bell-shaped. However, in the region where the jet was deflected, velocity profiles perpendicular to the original jet direction were nearly uniform, as if the profiles were measured in the same direction as the axial velocity of the jet. The shape of these profiles indicates that a crosswind changed the direction of the jet but did not destroy the integrity of the jet.

DISCUSSION

The results indicated that wind velocities and/or sprayer travel speed can have considerable effect on the air jet produced by an orchard air sprayer. Wind velocities, or apparent wind velocities (travel speed ± actual wind), greater than 10 mph and perpendicular to the sprayer jet deflected the jet nearly 70° at 8 inches from the model. Because the air jet transports a pest control agent into the plant canopy region, large jet deflections will reduce the capability of the sprayer to convey droplets to all parts of the canopy.

Additional experiments will be conducted to determine the effects of wind on air jets delivered by sprayers with different air outlet velocities and widths. An attempt will be made to determine the optimum air outlet configurations and velocities needed to provide the desired jet velocities with the minimum energy input.

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A Comparative Study of Selected Vineyard Training and Pruning Systems for 'Concord' Grapevines

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INTRODUCTION

In the spring of 1968, an experiment was initiated with Concord grapes to determine the relative merits of two training systems: the conventional Umbrella Kniffin (UK) and a system best described as a bilateral cordon, Single Curtain (SC). The vineyard was located at OARDC Horticulture Research Unit 2 at Wooster. Throughout the vineyard's initial 8-year history (1960-67), it had been maintained under uniform conditions and balanced pruned each year to the Umbrella Kniffin system (30 + 10), the predominant training method then used for Concord grapes in Ohio (2).

During the first year of the experiment (1968), the objective was to not only study the two systems, but to more fully understand the feasibility and effects of converting to the Single Curtain bilateral cordon system. The two systems are shown in Figure 1.

In a previous publication (1), results for a subsequent 8-year comparison (1968-75) were presented. Conclusions were that although considerable variation occurred from year to year in the vineyard, the two systems had a comparable yield potential. Also, with reasonable attention to detail, a conversion can be made to the SC system without loss of yield or quality.

Beginning in 1972 and continuing through 1979 (8 years), comparisons were continued between the UK and SC systems, but a mechanical pruning treatment was added to the Single Curtain trained vines (SCM). Data are also presented on the GDC system. However, it was not randomly integrated with the other plots.

MATERIALS AND METHODS

For the UK, SC, and SCM comparisons, each row in the vineyard was divided into four six-vine units. Only the center four vines in each unit were used for data collection. The remaining two functioned as guard vines between treatments. A total of 192 treatment vines were used in the experiment. As described in a previous publication (1), half of the six-vine units were randomly selected for modification to the Single Curtain (SC) in 1968. The remaining half of the vines continued to be maintained under the Umbrella Kniffin (UK) long cane system.

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The experiment continued without modification of the initial treatments until 1972, at which time half of the SC-trained vines were randomly selected for mechanical pruning with hand follow-up (SCM). Two additional rows in the vineyard were also trained to the Geneva Double Curtain (GDC) system as described by Shaulis, *et al.* (4, 5).

The mechanical pruning procedure for SCM vines consisted of the following: canes on each six-vine plot were cut off near the top of the cordon (top 180°) with electric hedging shears. Canes on the sides and underneath the cordon (bottom 180°) were cut to approximately two to five buds (Fig. 2). The original concept was to remove up to 80% of the pruning wood and leave five-bud canes. Since this procedure resulted in a removal of less than 50% of the necessary wood in 1972, more severe pruning was carried out in subsequent years. All SCM vines were then balanced pruned by hand following the initial mechanical pruning. Vines trained to the cordon systems were shoot positioned twice during the growing season, once in late June and again in July. None of the canes of SC, SCM, or GDC systems were tied to the trellis.

RESULTS AND DISCUSSION

As shown in Table 1, yield of the SCM vines was not changed during the initial year they were mechanically pruned (1972), nor in the two subsequent years (1973-74). In 1972, yield per node was the highest on the SCM and the lowest on the UK-trained vines. In 1973, the yield per node on the SCM vines was median between SC and UK-trained vines. It is of interest to note that growth of the UK vines was significantly greater than the other two treatments in 1972 (see 1973 pruning weights) and remained greater until the conclusion of the experiment. The reduced yields of all treatments in 1974 were due to a hailstorm that badly damaged the vines during the flowering and fruit set period. Even under these conditions, yield per node was lowest under the UK system.

Table 2 shows that mean pruning weights for 1975-78 continued to be greatest for vines in the UK system. For 3 out of 4 years, the pruning weights of the SC system were significantly greater than SCM. Excluding the GDC system, yields tended to be highest for the SC system. In 2 out of 4 years, the SCM had the lowest yield; the other 2 years the

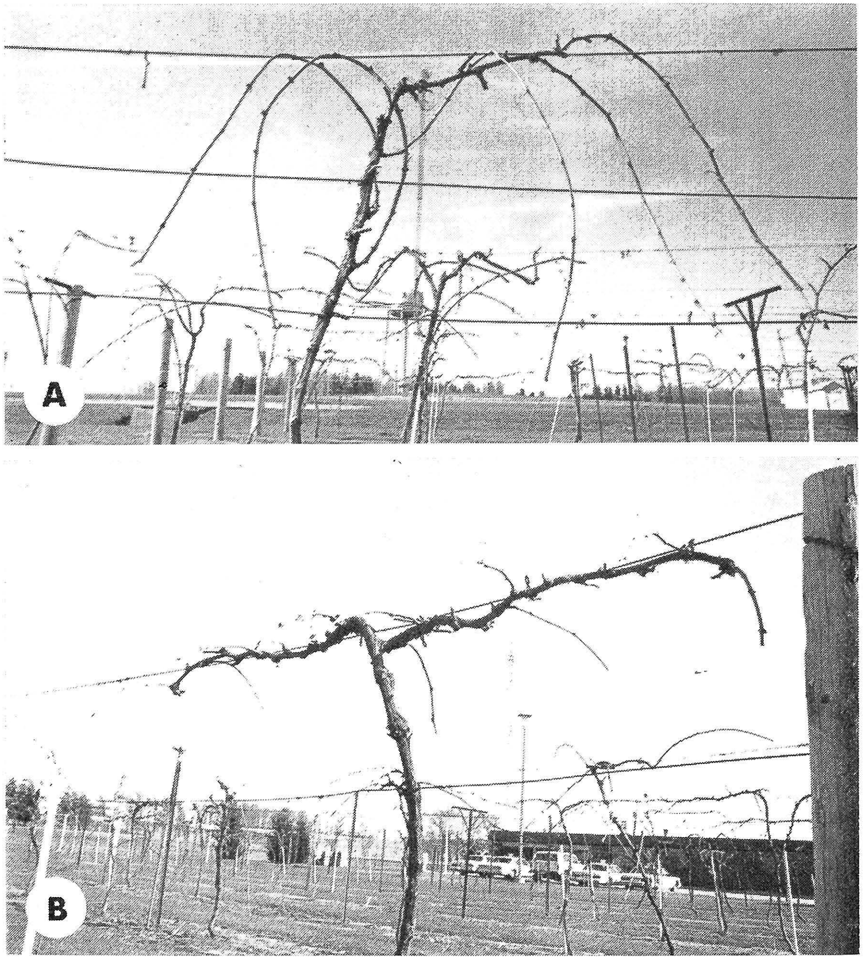

FIG. 1.—Examples of the Umbrella Kniffin (A) and Single Curtain bilateral cordon (B) training systems.

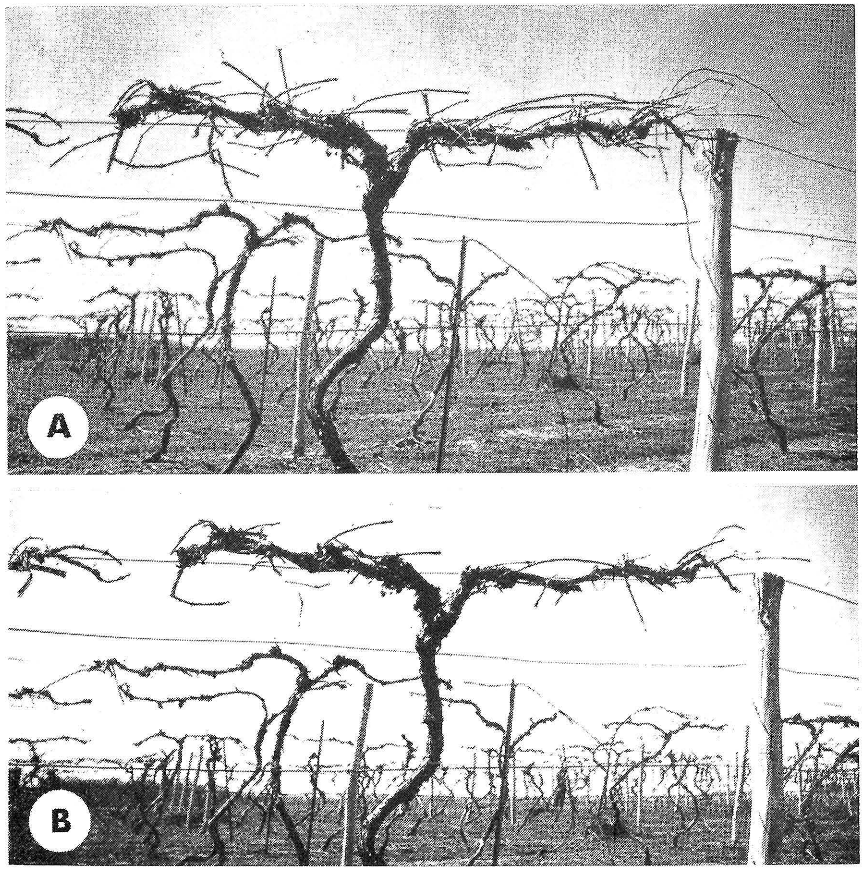

FIG. 2.—Mechanically pruned Concord grape vines trained to the Single Curtain bilateral cordon system before (A) and after (B) the hand pruning.

TABLE 1.—Comparison of Three Vineyard Training-Pruning Systems on Concord Grapes, OARDC, Horticulture Unit 2, Wooster, 1972, 1973, and 1974.

	1972			1973			1974		
	UK*	SC†	SCM‡	UK	SC	SCM	UK	SC	SCM
Yield/Vine-lb	21.5 a**	22.6 a	23.5 a	28.2 a	29.7 a	29.4 a	5.2 a	5.8 a	6.0 a
Cluster Wt.-lb	0.21a	0.18b	0.19ab	0.22a	0.20ab	0.19b	0.14a	0.14a	0.13a
Cluster No.	107b	125a	127a	127b	150a	153a	37c	40b	48a
Soluble Solids-%	15.0 a	14.5 b	14.4 b	13.6 a	13.6 a	13.6 a	14.6 b	15.2 a	15.1 a
Total Acids-%	0.65a	0.64a	0.65a	0.65a	0.66a	0.66a	0.93a	0.94a	0.94a
Pruning Wt.-lb	1.65a	0.97b	0.86b	3.45a	1.75c	2.34b	3.48a	1.83b	1.71b
Nodes Retained	37a	32b	30b	55a	41c	48b	51a	37b	37b
Clusters/Node	2.9	3.9	4.2	2.3	3.7	3.2	0.7	1.2	1.3
Yield/Node-lb	0.58	0.71	0.78	0.56	0.72	0.61	0.10	0.16	0.16

*UK=Umbrella Kniffin, hand pruned.
†SC=Single Curtain, hand pruned.
‡SCM=Single Curtain, machine pruned with hand follow-up.
**Mean separation by Duncan's multiple range test, 5% level, within years only.

UK system was lowest. Cluster weights of vines in the UK system were always equal to or greater than the other systems. Cluster numbers were always lowest for vines in the UK system, even though the bud number retained was usually higher. Soluble solids and total acids were generally not different among the treatments. Although not statistically comparable in this study, the GDC system was obviously the most productive and also had the highest percent soluble solids. The GDC system had pruning weights similar to the other cordon systems.

Mechanical pruning as carried out here, frequently, if not routinely, was to less than five buds per cane. The vine could be more logically characterized as being spur-pruned than short-cane-pruned (Fig. 2). Yet reasonable productivity was maintained. For Concord vines which the literature (3, 6) once stated were most productive on the 4th and 9th buds, this was an unexpected development. The reasons that productivity could be maintained were at least twofold: 1) the vines were *balanced pruned* by hand following the initial mechanical pruning; 2) the vines were *shoot positioned* which allowed sunlight penetration to the basal buds along the cordon and to the leaves (4).

In 1979, half of the vines trained to the UK system were shoot positioned (UKP) at identical times as the cordon systems (SC, SCM, GDC). As shown by Table 3, the procedure did not significantly change any of the previous production parameters. Percent soluble solids and cluster number tended to be reduced. This may have been due to the problems of shoot positioning UK system vines. Pruning weights for shoot positioned (UKP) vines taken in the winter of 1980 were lower than nonshoot positioned UK vines.

TABLE 2.—Comparison of Four Vineyard Training-Pruning Systems on Concord Grapes, OARDC, Horticulture Unit 2, Wooster. (Data represent means for the years 1975-78.)

	Training System			
	UK*	SC†	SCM‡	GDC**
Yield/Vine-lb	17.9	22.2	20.1	29.4
Cluster Weight-lb	0.20	0.19	0.18	0.18
Cluster No.	93	125	114	159
Soluble Solids-%	14.9	15.1	14.8	16.3
Total Acids-%	0.56	0.56	0.56	0.52
Pruning Weight-lb	3.6	2.4	2.3	2.6
Nodes Retained	52	44	42	44
Clusters/Node	1.79	2.85	2.73	3.43
Yield/Node-lb	0.34	0.50	0.48	0.67

*UK=Umbrella Kniffin, hand pruned.
†SC=Single Curtain, hand pruned.
‡SCM=Single Curtain, machine pruned with hand follow-up.
**GDC—Geneva Double Curtain, hand pruned.

TABLE 3.—Comparison of Five Vineyard Training-Pruning Systems on Concord Grapes, OARDC, Horticulture Unit 2, Wooster, 1979.

	Training System				
	UKP*	UK†	SC‡	SCM**	GDC††
Pruning Wt-lb-1979	4.02a‡‡	3.81a	2.41b	2.88b	4.28
Pruning Wt.-lb-1980	4.05b	6.13a	4.06b	4.15b	3.70
Nodes Retained	51a	60a	43c	47b	56
Yield/Vine-lb	20.0 a	20.9 a	20.1 a	16.6 b	37.5
Cluster No.	89ab	96a	84ab	78b	158.5
Cluster Wt.-lb	0.22a	0.22a	0.24a	0.21a	0.24
Soluble Solids-%	14.7 b	15.1 ab	15.1 ab	15.5 a	15.7
Total Acid-%	0.62a	0.60a	0.55a	0.59a	0.44
Clusters/Node	1.75	1.92	1.95	1.66	2.85
Yield/Node-lb	0.40ab	0.42ab	0.47a	0.36b	0.67

*UKP=Umbrella Kniffin, shoot-positioned, hand pruned.
†UK=Umbrella Kniffin, non-shoot-positioned, hand pruned.
‡SC=Single Curtain, hand pruned.
**SCM=Single Curtain, machine pruned with hand follow-up.
††GDC=Geneva Double Curtain, hand pruned.
‡‡Mean separation by Duncan's Multiple Range Test, 5% level.

SUMMARY AND CONCLUSIONS

The results indicate that it is entirely feasible to remove 50-80% of the dormant 1-year-old cane growth by mechanical pruning and still maintain productivity. Also, the necessity to long-cane prune Concord grapevines has been shown to be in error both by these studies and others (4, 5). It has, in fact, been shown to be more related to training-light relationships than varietal characteristics.

Concord grapevines in this study were pruned and trained to a five-bud cane, bilateral cordon at standard commercial vineyard densities for a total of 12 consecutive years. During that time, production from these vines was as great and generally greater than those on the Umbrella Kniffin system. Production at least equal to the Umbrella Kniffin system was also achieved for 8 years by mechanically pruning the canes to two to five buds followed by hand and balanced pruning.

The fundamental value of the experiment was at least twofold: 1) to show that yield and quality can be maintained under the Single Curtain (SC) system; and 2) to show that Concord vines can be productive when mechanically pruned (SCM treatment) as long as the proper balance can be maintained between fruiting and vegetative growth.

A rating of productivity from high to low as a result of this study would have to be: 1) Geneva Double Curtain; 2) Single Curtain hand-pruned; 3) Single Curtain machine-pruned (hand follow-up); and 4) Umbrella Kniffin. Yield per retained node and clusters per retained node would also follow this same order. The Geneva Double Curtain (GDC) was obviously the most productive system of those tested. However, many growers are *not converting* to this system primarily for two reasons: 1) expense and 2) they do not have access to a harvester that will pick from this trellis.

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Effects of Selected Soil Applied Herbicides on Grapes

JOMO MacDERMOT and GARTH A. CAHOON[1, 2]

INTRODUCTION

Herbicides are widely used in established vineyards but only recently have a few been registered for use in newly planted vineyards (5). In Ohio, commercial grape growers voted "weed control" the most important vineyard problem (1). Newly planted vines suffer intense competition from weeds. Lange (9) estimates the growth of grapes can be reduced 50% the first year if weeds are not controlled.

Field and greenhouse experiments were included in these studies. The first section reports the weed control efficacy and toxicity of three soil applied herbicides: methazole (2-3,4-dichlorophenyl)-(4-methyl-1,2,4 oxadiazolidine-3,5-dione) (Probe)[3], FMC 25213 (4-2-ethyl) 5-methyl-cis-5-(2-methylbenzyl-oxy)-1,2,dioxane), and butralin (N-sec-butyl-4-tert-butyl-2,6-dinitroaniline) (Amex)[3]. All were used at two rates with two application methods: soil incorporation and surface spray. The herbicides were tested in an experimental vineyard planted to *V. vinifera* cv. W. Riesling and *V. labruscana* b. cv. Catawba.

In a subsequent greenhouse experiment, treatments were designed to measure the response and sensitivity of W. Riesling vines to increasing rates of two soil applied herbicides: methazole (Probe) and FMC 25213.

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[2]Work was supported in part by the Lonz Foundation of Middle Bass Island, Ohio.

[3]Trade names.

FIELD STUDIES: Effects of Methazole, FMC 25213 and Butralin on Weed Growth and Toxicity of W. Riesling, *V. vinifera,* and Catawba, *V. labruscana* b.

MATERIALS AND METHODS

The field site was Canfield silt loam soil that had been part of a grass-legume meadow located at the OARDC, Wooster. Prior to treatment, the field was rototilled and free of vegetation. The experiment was arranged in a split plot design with six randomized complete blocks. Main plots were 1 m^2 and corresponded to the herbicide treatments. These plots were diagonally divided into sub-plots and the grape species were planted therein. Each block had 14 treatments, including controls (Table 1).

TABLE 1.—The Influence of Three Herbicides, Two Rates and Two Modes of Application on Weed Growth and Toxicity to Two Grape Cultivars.

	Weed Growth (Dry wt. gms. per 1 m^2)*			Toxicity to Vines†	
Treatment (kg/ha)	Pigweed	Broadleaved‡	Grass**	Catawba	Riesling
Methazole 2.25 Inc††	400.1a‡‡	111.6d	274.6a	0.13	0.20
2.25 Surf	31.0g	44.6e	100.3d	0.42	0.50
9.0 Inc	38.1g	70.1e	33.3fg	4.69	1.91
9.0 Surf	30.3g	1.3f	2.2i	3.46	2.78
FMC 25213 2.25 Inc	67.0f	265.3a	42.0f	0.16	0.33
2.25 Surf	44.1g	211.6b	22.3gh	0.25	0.13
9.0 Inc	0.0h	160.3c	5.6i	0.16	0.69
9.0 Surf	2.3h	108.0d	0.0i	0.16	0.08
Butralin 2.25 Inc	163.8d	266.6a	77.0e	0.25	0.25
2.25 Surf	209.2c	103.5d	140.6c	0.29	0.08
4.5 Inc	143.5e	182.3c	103.8d	0.20	0.04
4.5 Surf	0.0h	119.3d	16.8ghi	0.29	0.08
Weedy Control	384.5b	230.3b	177.0b	0.08	0.04
Hand Weeded Control				0.33	0.08

*All data the mean of six replications.
†Mean of six vines scored four times during 11 weeks. 0 = no damage, 6 = plants dead.
‡Principally purslane, chickweed, dandelion; frequently shepherdspurse, smartweed, oxalis, galinsoga; rarely lambsquarters, carpetweed, dock, and plantain.
**Principally large crabgrass, fall panicum, and annual bluegrass; frequently barnyard grass; rarely quackgrass.
††Inc=Soil Incorporation. Surf=Surface Spray.
‡‡Mean separation in columns by Duncan's multiple range test, 5% level.

The herbicides were prepared and calibrated for 1 m^2 and applied with a hand applicator. All preplant treatments were soil incorporated. The vines which were transplanted into the plots were obtained from cuttings propagated in peat pots, well-rooted and leafy. At planting time the outside layer of the peat pot was partially removed to allow better contact of the roots with the soil. Care was taken to avoid mixing soil layers. During the surface application, applicators were held close to the ground to avoid spraying the grape leaves. The soil was moist at this time and 2.2 cm rain fell within the day.

The experiment was started on June 23 and continued for 11 weeks, after which time the weed growth per main plot was evaluated. All pigweed plants *(Amaranthus retroflexus)* were counted, cut off at ground level, oven dried, and weighed. Other broadleaved weeds were combined, dried, and weighed. Grass plants were likewise harvested. All weed data were statistically analyzed. Grape toxicity ratings were based on visual observations over the 11-week period.

RESULTS AND DISCUSSION

Methazole at the low rate, 2.25 kg/ha, when soil incorporated failed to control either pigweeds or grassy weeds (Table 1). The dry weight of other broadleaved weeds was reduced by this treatment but this effect could have been due to severe competition from pigweeds and grass. The surface spray application at the low rate significantly controlled all classes of weeds. The high rate, 9.0 kg/ha, of methazole effectively reduced the weed growth of all three classes of weeds regardless of application method. However, the surface spray gave better control of broadleaved and grassy weeds. When the 2.25 kg/ha surface application is compared to the 9 kg/ha soil incorporation application, the only significant difference is in the control of grassy weeds, with the higher rate more effective.

Methazole at 2.25 kg/ha proved substantially non-toxic to both grape species. The high rate, 9 kg/ha, whether incorporated or sprayed was phytotoxic to both grape cultivars, Catawba being more sensitive than Riesling. The primary toxicity symptom was a veinal yellowing followed by necrotic lesion development, ultimately resulting in extensive regions of brown, dead tissue.

The initial veinal yellowing appeared first on the older leaves and was evident within 10 days of treatment. This rate and distribution of methazole movement through the plant agrees with published reports (6, 14). When photos of grape leaves damaged by methazole (10) (see Greenhouse Studies) are compared to grape damage by diuron (9), no differences are noted. It has been shown that methazole is rapidly metabolized in plants to at least two identifiable compounds, one of which [1-(3,4 dichlorophenyl)-3-methyl urea (DCPMU)] is known to be phytotoxic and closely resembles monuron and diuron (3, 7). Methazole when soil incorporated is also reported to cause abnormal root growth in Riesling (see Greenhouse Studies).

FMC 25213 at 2.25 kg/ha, whether incorporated or sprayed on the surface, effectively controlled pigweed and grassy weeds but neither application reduced the growth of other broadleaved weeds. At the low rate the surface spray was more effective in weed control than the incorporated treatment. This herbicide at 9.0 kg/ha gave excellent control of pigweed and grass but only fair control of other broadleaved weeds. At the high rate the surface application gave better control of broadleaved weeds. FMC 25213 treatment caused no damage to either grape cultivar.

On pigweeds and grass, the low rate of butralin (2.25 kg/ha) was more effective when soil incorporated than when surface applied. In contrast, however, the high rate (4.5 kg/ha) effectively controlled these weeds when surface applied. Overall, butralin gave only fair weed control of broadleaved weeds and both rates, when surface applied, were equally effective. All butralin treatments controlled grassy weeds when compared to controls. The low rate was more effective on grass when soil incorporated. The high rate, however, gave better results when surface applied. No butralin treatment damaged either grape cultivar.

GREENHOUSE STUDIES: Response of W. Riesling *V. vinifera* to Four Application Rates of Methazole and FMC 25213.

MATERIALS AND METHODS

Quantities of herbicides equal to 1.125, 2.25, 2.375, and 4.5 kg/ha were prepared and applied to a soil mix of Canfield silt loam, sand, and perlite (1:1:1). After thorough mixing, the soil was distributed into 3-liter plastic pots. Uniform, well-rooted, leafy hardwood cuttings were chosen, randomly assigned, and planted bare root in the soil mix. The experimental design was a randomized complete block with five replications.

The treatments were four rates of each herbicide at approximately a 6-inch incorporation depth, plus controls. Plants were watered and placed under greenhouse conditions. Supplemental light (about 6000 lux, incandescent plus fluorescent) was supplied from 6 a.m. to 2 a.m. daily. Greenhouse temperatures were set at 20° C day and 12.7° C night.

At regular intervals each vine was evaluated for visual damage.

The experiment was established in mid-February and maintained for 7 weeks. The above ground portion of each vine was then cut off, oven dried at 70° C, and weighed. The roots were washed, inspected, oven dried, and weighed. Leaf contents of N, P, K, Ca, and Mg were determined; N by micro-Kjeldahl, Ca and K by flame photometry (Varian 1200), Mg by atomic absorption (Varian 1200), and P by molybdate-vanadate reagent and a B & L Spectronic 20.

RESULTS AND DISCUSSION

Methazole at the lowest rate produced no visible toxic symptoms. At higher rates the leaves showed varying degrees of yellowing, veinal chlorosis, and brown necrotic lesions (Fig. 1). These symptoms were evident on old and new leaves and appeared after the fifth week. Also noted, especially at the highest rate, was occasional terminal petiole abscission, tendril browning, and leaf cupping.

Methazole also had visible effects on the roots (Figs. 2 and 3). Fig. 2 shows the short, stubby root system of a vine planted in the highest rate, 4.5 kg/ha. All treatment groups except the lowest rate showed root abnormalities. Generally the roots were not the fine, fibrous type found in the controls but were rather thick and short with a somewhat bulbous apical region. These abnormal roots proliferated at random locations, often far from the woody base and near the end of an existing root. An increase in adventitious roots arising from the woody stem was also observed (Fig. 3). These adventitious roots were thicker and had fewer fibrous tertiary roots when compared to controls.

Methazole is known to be absorbed through the roots and metabolized there, by susceptible species, to DCPMU which closely resembles the substituted ureas, monuron and diuron (3, 6). Monuron is known to decrease net photosynthesis in apple leaves (11) and diuron inhibits root growth of several species (2, 9). Species tolerant of methazole, *e.g.,* cotton, convert DCPMU to non-toxic DCPU (4).

Only root dry weight, percent N, and percent Ca differed from controls (Table 2). Leaf percent Ca was significantly affected by the two highest rates of methazole but other parameters were not reduced by methazole treatments. Whether the reduction of leaf percent Ca was caused by methazole's direct effect on ion uptake or is related to a possible effect on root growth and subsequently to reduced root surface area for ion uptake, as Smith and McVeigh propose (12), is unknown. Williams (13) reports root and shoot growth inhibition of container grown ornamentals when sprayed with methazole but he specu-

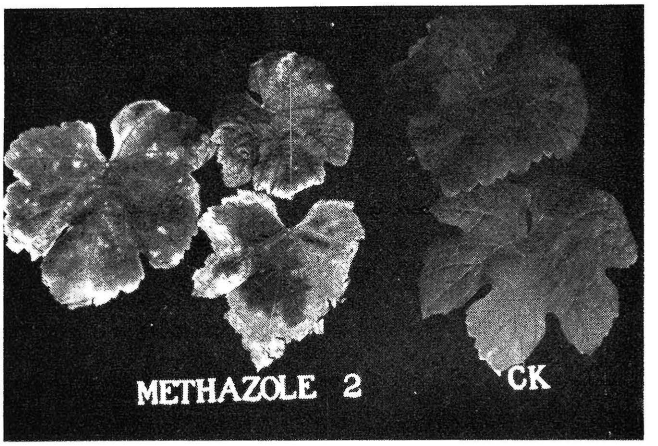

FIG. 1.—Comparison after 7 weeks between Riesling cuttings grown in soil treated with 2.25 kg/ha methazole and non-treated.

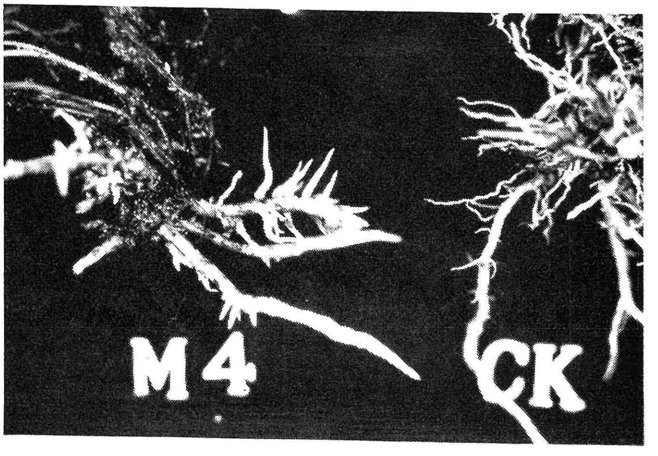

FIG. 2.—Close-up comparison after 7 weeks between roots of Riesling cuttings grown in soil treated with 4.5 kg/ha methazole and non-treated.

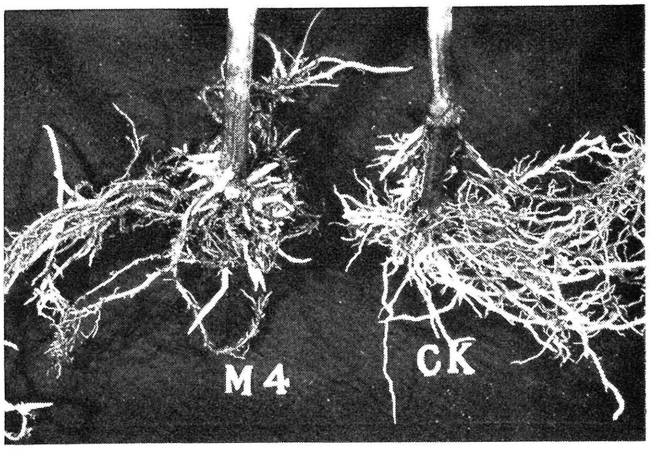

FIG. 3.—Comparison after 7 weeks between roots of Riesling cuttings grown in soil treated with 4.5 kg/ha methazole and non-treated.

TABLE 2.—Effects of Varying Rates of Methazole and FMC 25213 on Root Dry Weight, Leaf Percent N, and Leaf Percent Ca of Greenhouse-grown Riesling Cuttings, 7 Weeks After Treatment.

Treatment	Root Wt. gms	Percent N	Percent Ca
Methazole 1.125 kg/ha	2.21	1.53	1.09
Methazole 2.25 kg/ha	1.57	1.65	0.98
Methazole 3.375 kg/ha	0.94	1.29	0.84
Methazole 4.50 kg/ha	1.13	1.50	0.85
FMC 25213 1.125 kg/ha	1.85	1.64	1.24
FMC 25213 2.25 kg/ha	2.81	1.78	1.26
FMC 25213 3.375 kg/ha	2.83	1.65	1.18
FMC 25213 4.50 kg/ha	1.51	2.60	1.07
Control	1.33	1.58	1.12
LSD .05	1.01	0.29	0.18

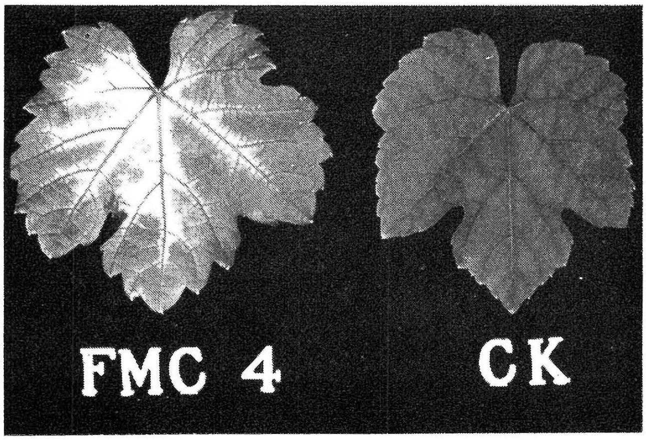

FIG. 4.—Comparison after 7 weeks between leaves of Riesling cuttings grown in soil treated with 4.5 kg/ha FMC 25213 and non-treated.

lates his results may be due to foliar absorption and phytotoxicity.

FMC 25213 caused no visible damage at the lowest rate (1.125 kg/ha). At higher rates, toxic symptoms appeared on the leaves. Figure 4 shows the leaf chlorosis symptoms that developed after 7 weeks. The yellowing was not distinctly in the veins but also appeared near the margins in isolated spots. At the highest rate (4.5 kg/ha), the damage seemed to follow the veinal pattern, radiating from the blade-petiole juncture. These symptoms occurred more often on the older, larger leaves and did not appear until the sixth week. FMC 25213 produced no visible root damage. The anomalous increases in root dry weight and percent leaf N (Table 2) associated with FMC 25213 remain to be further investigated.

The data presented here and elsewhere (9) indicate that soil levels greater than 1.5 kg/ha methazole are toxic to Riesling vines. Symptoms of toxicity include damage to roots and leaves which mimic monuron damage. FMC 25213 produced only leaf damage at rates greater than 1.125 kg/ha.

SUMMARY AND CONCLUSIONS

Field Studies: The herbicides methazole (75 WP) (Probe) and FMC 25213 (4EC) were applied at 2.25 and 9.0 kg/ha with two application methods, surface spray or soil incorporation. Butralin (4EC) (Amex) at rates of 2.25 and 4.0 kg/ha was likewise applied. The low rate of methazole, when surface applied, gave adequate weed control and was non-toxic to newly planted vines. Methazole at 9 kg/ha gave superior weed control but was toxic to vines, with symptoms resembling diuron damage. Only the high rate of FMC 25213 controlled all classes of weeds with no evidence of grape toxicity. Butralin was non-toxic to vines and was most effective at the high rate when surface applied, not incorporated.

Greenhouse Studies: The lowest rate of the soil applied herbicides, methazole 75WP (Probe) and FMC 25213, 4EC, 1.125 kg/ha, caused no visible damage to Riesling vines. Higher rates of each caused leaf damage. Methazole produced abnormal root growth.

Although none of the herbicides tested are presently approved for use in newly planted grape vineyards, the data provide a range of efficacy for such materials.

The methodology utilized in these studies is also applicable to the testing of other such herbicides.

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Evaluation of Aromatic Compounds and Virgin Females as Attractants for Rose Chafer[1]

ROGER N. WILLIAMS[2], TERRENCE P. McGOVERN[3], and MICHAEL KLEIN[4]

INTRODUCTION

The rose chafer, *Macrodactylus subspinosus* (F.), (Fig. 1) is a pest of fruit crops in sandy areas in much of the eastern half of the contiguous United States. It attacks foliage and fruit alike of apples, peaches, grapes, and many other plants. The primary concern with this insect in Ohio is the possible complete elimination of grapes at bloom, and shortly thereafter, through the feeding of chafer adults. Heavy infestations of the rose chafer occur most commonly in light sandy soils where the immature stages feed on grass roots.

Johnson (1) was the first to report trapping studies for the rose chafer. Unfortunately, he did not mention the lure utilized. The only other article on the attractancy of various aromatic compounds to rose chafer adults was reported in 1982 by Williams and Miller (2). In these tests it was established that caproic acid and valeric acid were the best attractants.

The objective of the present study was to evaluate compounds related to caproic and valeric acids, attempting to find an improved attractant. The goal is to find an attractant which is suitable for monitoring rose chafer adults.

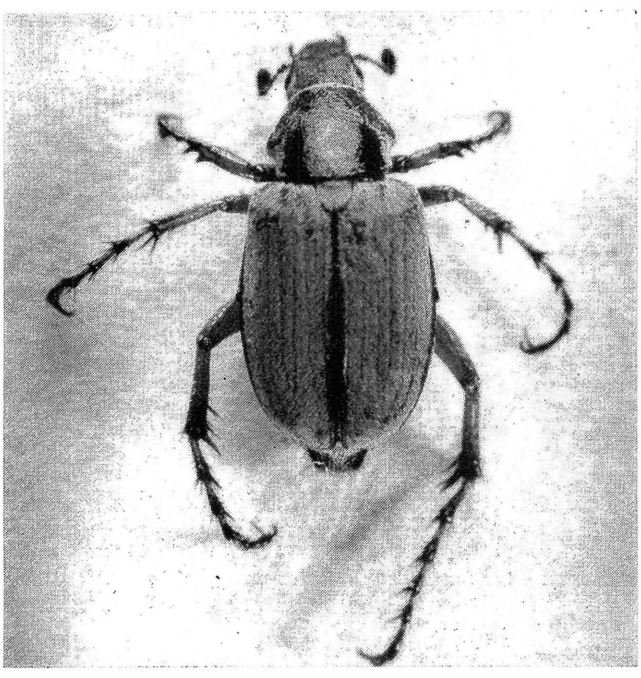

FIG. 1.—Adult of the rose chafer.

METHODS AND MATERIALS

All attractancy evaluations were conducted on the Ganley Farm at North Kingsville, Ohio, during 1981. This location usually has a very high incidence of rose chafers. Two types of tests were conducted. In the first, only synthetic chemical compounds were compared to the standards, caproic acid and valeric acid. In the second the standards were compared to virgin males and females.

Test I.—Synthetic Attractants

The majority of the chemicals used in this study were carboxylic acids having four to eight carbon atoms. In addition, there were some anhydrides, acid chlorides, and aldehydes related to the standards. Due to the large number of new compounds (33) to be compared, two separate tests were run. The compounds are listed in Tables 1 and 2.

Lures consisted of No. 2 Johnson & Johnson cotton rolls saturated with the candidate compounds. These rolls were placed in a 7-dram plastic vial lined with aluminum foil. This plastic vial was in turn placed inside the lure receptacle of a standard Ellisco Japanese beetle trap.

Test II.—Attraction to Virgin Adults

A separate experiment was set up using virgin males and females. These were obtained by digging grubs in early spring and rearing them in the laboratory. Virgins were placed in a small screen cage which was inserted into the Ellisco trap in the same manner as the cotton roll.

The traps were placed in a sod field adjacent to a 'Concord' vineyard. Traps were suspended 1 m above ground from steel rods and spread 8 m apart. Each candidate lure was replicated four times in randomized complete blocks. Traps were rebaited weekly and beetles were collected on alternating 3 and 4 day intervals.

RESULTS AND DISCUSSION

In tests with the first 17 experimental compounds (Table 1), it was found that although most of the compounds attracted more beetles, none of the synthetic compounds differed significantly from the

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TABLE 1.—Group 1—Rose Chafer Attractant Study at North Kingsville, Ohio, 1981.

		Mean Number Beetles/Trap			
		June 12-15	June 15-19	June 19-22	Total
1.	2-Methylpropanoic acid	14.25	22.50	9.50	46.25b*
2.	3-Methylbutyric acid	17.00	27.00	9.25	53.25b
3.	2-Methylpentanoic acid	11.75	26.25	13.75	51.75b
4.	3,3-Dimethylbutyric acid	12.25	25.75	8.25	46.25b
5.	4-Methylpentanoic acid	7.50	22.50	5.50	35.50b
6.	2,2-Dimethylpentanoic acid	9.50	17.25	5.25	32.00b
7.	2-Ethylbutyric acid	10.25	20.50	7.50	38.25b
8.	Hexanoic anhydride	17.00	27.75	5.75	50.50b
9.	2-Methylbutyric acid	14.75	18.25	7.00	40.00b
10.	3-Methylpentanoic acid	12.25	14.25	4.75	31.25b
11.	Cyclobutanecarboxylic acid	14.25	28.50	10.75	53.50b
12.	Cyclohexanecarboxylic acid	9.25	22.50	7.00	38.75b
13.	Cyclopentanecarboxylic acid	7.50	27.25	9.50	44.25b
14.	Cyclopropanecarboxylic acid	8.75	28.25	12.75	49.75b
15.	5-Norbornene-2-carboxylic acid	13.75	24.00	5.00	42.75b
16.	Norbornene-2-carboxylic acid	7.00	13.75	6.75	27.50b
17.	Butyric anhydride	12.25	17.00	9.25	38.50b
18.	Valeric acid	22.75	23.25	7.75	53.75b
19.	Caproic acid	36.50	53.50	17.75	107.75a
20.	Check (H_2O)	8.00	14.75	5.75	28.50b

*Means followed by same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

TABLE 2.—Group 2—Rose Chafer Attractant Study at North Kingsville, Ohio, 1981.

		Mean Number Beetles/Trap				
		June 22-26	June 26-29	June 29-July 2	July 2-July 10	Total
21.	Valeric anhydride	8.75	7.50	5.25	8.50	30.00a*
22.	2-Methylhexanoic acid	4.00	2.50	1.75	1.75	10.00dc
23.	Valeryl chloride	9.00	6.25	6.00	3.25	24.50dcba
24.	Hexanoyl chloride	4.50	3.25	4.25	2.75	14.75cdba
25.	Butyraldehyde	9.50	0.75	1.50	0.50	12.25dc
26.	Valeraldehyde	4.00	2.50	2.75	2.75	12.00dc
27.	Hexanal	7.50	4.25	5.50	2.50	19.75dcba
28.	2-Chlorobutyric acid	3.50	3.75	3.25	2.00	12.50dc
29.	4-Chlorobutyric acid	5.50	3.50	3.75	4.00	16.75dcba
30.	2,2-Dimethylpropanoic acid	1.75	0.75	1.00	2.50	6.00d
31.	2-Hexenoic acid	7.25	6.75	2.75	4.25	21.00dcba
32.	2-Pentenoic acid	8.50	8.00	5.00	6.75	28.25ba
33.	2-Butenoic acid	3.25	4.00	1.50	1.25	10.00dc
34.	3-Hexenoic acid	4.50	5.00	1.50	2.75	13.75dcb
35.	2-Methyl-2-butenoic acid	4.75	3.50	1.75	2.00	12.00dc
36.	3-Methyl-2-butenoic acid	1.75	1.50	2.50	1.00	6.75d
37.	Check (blank)	2.00	2.00	1.50	0.50	6.00d
38.	Valeric acid	3.75	4.50	6.50	5.25	20.00dcba
39.	Caproic acid	10.75	8.50	5.00	4.00	28.25ba
40.	Check (H_2O)	2.00	2.25	1.25	1.50	7.00d

*Means followed by same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

TABLE 3.—Rose Chafer Virgin Attractant Study at North Kingsville, Ohio, 1981.

	Mean Number of Beetles/Trap*							
	June 12-15	June 15-19	June 19-22	June 22-26	June 26-29	June 29-July 2	July 2-10	Total
1. Virgin females	3.50	8.50	2.25	1.25	1.75	0.00	0.75	18.00b†
2. Caproic acid	20.75	27.75	7.00	4.50	4.75	3.50	5.75	74.00a
3. Valeric acid	13.75	27.25	6.50	9.50	7.75	3.50	0.75	69.00a
4. Check	2.75	7.25	2.00	0.25	0.75	0.25	2.50	15.75b
5. Virgin male	4.00	5.00	2.00	1.00	0.25	0.50	1.00	13.75b

*All attractants were renewed in the traps on June 15, 19, and 22. June 26 was the last date when caproic and valeric acids were added.

†Means followed by same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

check. One standard, caproic acid, was better than any other compound. Interestingly, the other standard, valeric acid, attracted more beetles than any of the 17 compounds under study, yet it was not significantly different from the check.

In testing the second group of 16 compounds (Table 2), valeric anhydride and 2-pentenoic acid were equally as effective as caproic acid. In all, seven compounds were not significantly different from the caproic acid. These compounds will be the subject of future attractancy studies.

A definite trend in the trappable population can be seen by observing the mean number of beetles per trap starting in Table 1 and following in Table 2. Notice catches using caproic acid, for example. Numbers caught in the first period are relatively high, reaching a summit in the second period; they then gradually decline from 17+ to 10+ to 8+ to 5 and finally to 4. The early collections listed in Table 1 clearly demonstrate that of the compounds tested, caproic acid is superior.

In the virgin attractant study (Table 3), caproic and valeric acids each attracted significantly more beetles than the check, virgin males, or virgin females. Little more can be said here except that the virgin insects did not appear more attractive than the check. Additional investigations are underway to try to establish the presence of a sex attractant in the rose chafer.

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Botrytis cinerea "Gray Mold" Isolates from Strawberry Resistant to Benlate in Ohio

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INTRODUCTION

Gray mold, one of the most common and serious diseases of strawberry, is caused by the fungus *Botrytis cinerea*. The disease can affect petals, flower stalks (pedicels), fruit caps, and fruits (Fig. 1). In wet seasons no other disease causes as great a loss to flowers and fruits.

The application of fungicides through bloom and harvest is essential for gray mold control. Benlate (50% wettable powder) has been one of the most effective and widely used fungicides for gray mold control. However, there have been several reports of Benlate-resistant strains of *B. cinerea* on several different crops (1, 3, 4, 5, 6). The purpose of this study was to determine if Benlate-resistant strains of *B. cinerea* are present in Ohio strawberry fields.

MATERIALS AND METHODS

Strawberry fruits (cultivar 'Midway') infected by *B. cinerea* were collected from a commercial planting near Wooster and the OARDC Snyder Farm. The commercial planting had a long history of Benlate use; the strawberries at Snyder Farm had never been treated with Benlate.

Ten isolates were collected from each location and maintained on potato dextrose agar (PDA). In an initial screening for resistance, 5 mm agar plugs were taken from the edge of 5-day-old cultures of *B. cinerea* and transferred to the center of petri plates containing PDA amended with 1 ppm Benlate. Amended PDA was prepared by adding the appropriate concentration of Benlate to liquified PDA after autoclaving (45 C). There were three plates per isolate.

Isolates which grew on Benlate amended PDA in the initial screening were considered resistant and selected for further study. Resistant isolates were grown on nonamended PDA, then transferred as previously described to PDA amended with 0, 1, 10, 50, 100, 500, 1,000, or 2,000 ppm (a.i.) Benlate. There were five plates per concentration and isolate. Mycelial growth was measured daily for 5 days. The experiment was repeated once.

RESULTS AND DISCUSSION

Four isolates (two from the commercial planting and two from Snyder Farm) were highly resistant to Benlate (Table 1). Benlate-sensitive isolates did not grow on PDA amended with 1 ppm Benlate (Fig. 2). Above 1 ppm Benlate, mycelial growth was reduced with each increase in concentration, but growth could not be prevented at any concentration tested. After 5 days, all resistant isolates had some growth, even at 2,000 ppm.

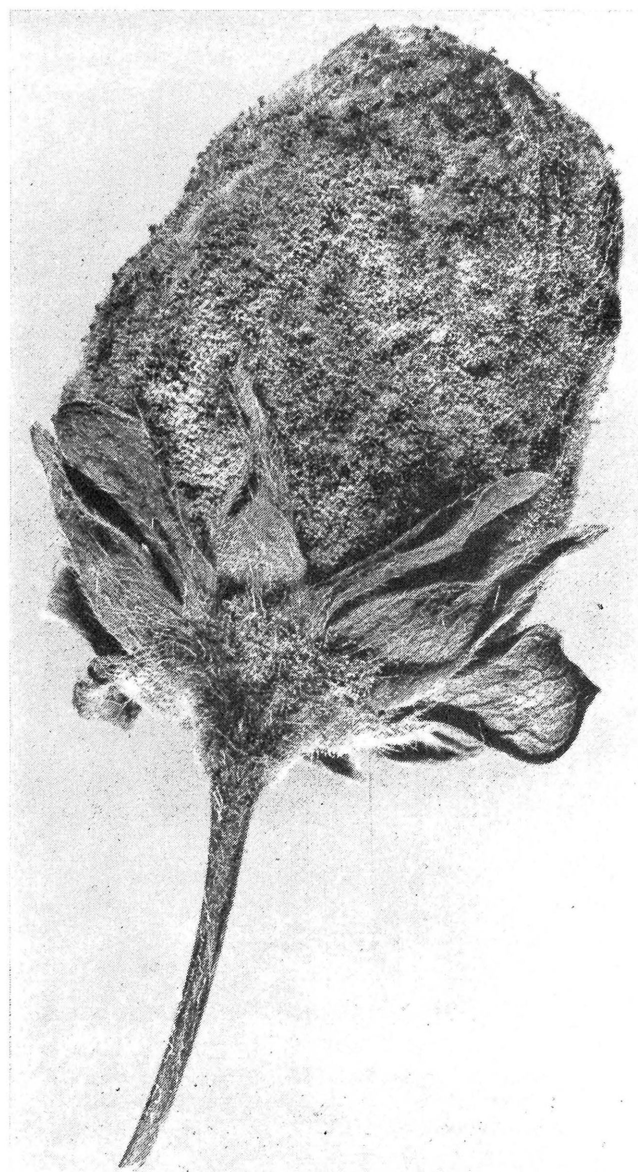

FIG. 1.—Strawberry fruit infected with Botrytis cinerea **"Gray Mold".**

[1]Graduate Research Associate and Assistant Professor, respectively, Dept. of Plant Pathology.

TABLE 1.—Growth of Benlate-resistant* *Botrytis cinerea* Mycelium on Potato Dextrose Agar Amended with Various Concentrations of Benlate.

Benlate Concentration (ppm a.i.)	Growth (cm) After 5 Days†			
	Isolate BO 1-2	Isolate BO 1-8	Isolate BO 1-10	Isolate BO 2-3
0	9‡	9	9	9
1	9	9	9	9
10	6.4	6.5	6.4	6.7
50	5.1	5.5	5.7	5.8
100	5.1	5.2	5.2	5.5
500	3.9	3.6	3.7	3.8
1,000	2.9	2.7	2.4	3.1
2,000	1.1	0.7	0.7	1.0

*All Benlate sensitive isolates would not grow at 1 ppm Benlate.
†Mean of five plates.
‡9 = growth to edge of petri plate.

The labeled rate of Benlate on strawberries is 1 lb product per acre during bloom and ½ lb product per acre post bloom. In dilute spray (250 gal/acre), the 1 and ½ lb rates would result in approximately a 450 and 225 ppm concentration, respectively, in the spray tank. Obviously, if Benlate-resistant strains of *B. cinerea* are predominant in the field, Benlate will not provide control, and alternative fungicides should be selected.

Problems with fungicide resistance in plant pathogenic fungi are constantly increasing. An exact method for preventing the problem is not known: however, many scientists suggest that fungicide mixtures (combinations) or alternating sprays with different fungicides may aid in reducing the development of resistance. The Ohio spray recommendations for strawberries (2) suggest that Benlate should always be used in combination with another fungicide such as Captan or Folpet.

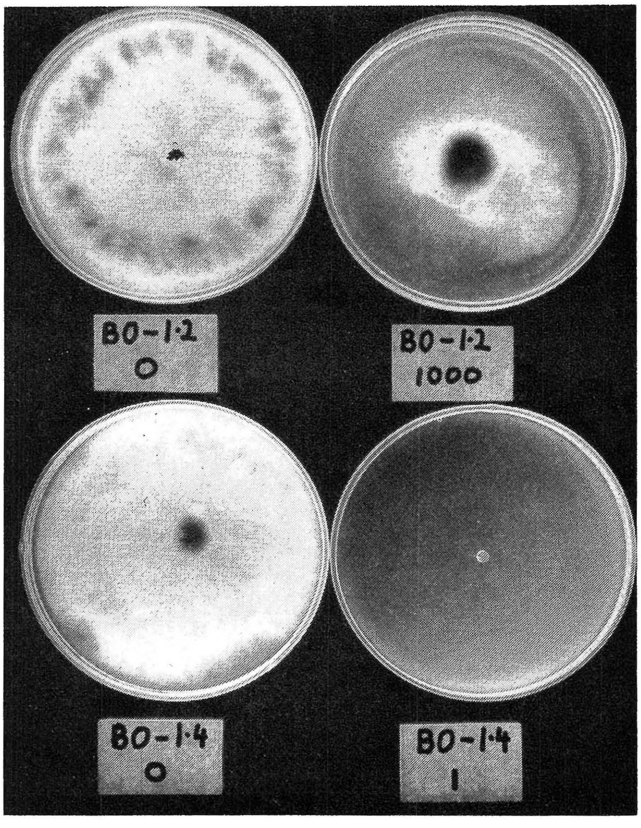

FIG. 2.—Upper left—plate containing Benlate-resistant *Botrytis cinerea* isolate BO 1-2 growing on PDA without Benlate; upper right—isolate BO 1-2 growing on PDA amended with 1,000 ppm Benlate. Lower left—plate containing Benlate sensitive isolate BO 1-4 growing on PDA without Benlate; lower right—isolate BO 1-4 on PDA amended with 1 ppm Benlate. All plates were incubated for 5 days.

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